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The Journal of HEREDITY

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INHERITANCE OF MENTAL TRAITS . . . . . (REVIEW)

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Date of issue of this number, July 11, 1921.

ROUND TIP TOBACCO AT THE LEFT COMPARED WITH HAVANA TOBACCO AT THE RIGHT

Here is a good illustration of the plant breeders' art. Three essentially different requirements were met in the production of a new tobacco now known as Round Tip which produces the finest cigar wrappers in the United States. The manufacturers and consumers of cigars have thus been satisfied as well as the growers who demand a strong, many-leaved, disease resistant plant. The new hybrid is shown at the left in the photograph. Compare its leaves with those of the Havana plants at the right. (Frontispiece.)

ROUND TIP TOBACCO— A PLANT "MADE TO ORDER"

From Specifications Drawn by Manufacturers and Consumers of Cigars, and the Growers of Tobacco, a New Plant is Grown to Satisfy the Demands of Commerce.

E. M. East,
Bussey Institution, Harvard University, and
D. F. Jones,
Connecticut Agricultural Experiment Station

A NEW type of cigar wrapper tobacco known to the trade as Round Tip, has given such evidence of commercial success that its origin may be of some interest, particularly as it is one of the few instances where a plant was actually made to order with the specifications drawn beforehand.

The manufacturer of cigars, knowing the demands of the consumer, calls for numerous qualities in the leaf he uses to enclose his wares. Primarily of course, it must burn rather freely—but not too freely—and must leave a gray-white ash which does not flake off at each puff of the ultimate consumer. The flavor must be of that peculiar character acceptable to the connoisseur, which may be described as neither earthy nor bitter but somewhere in between. Possession of the delicate aroma so dear to the heart of the confirmed smokers is not essential. The aroma of a cigar is furnished by the leaf used as filler; but the wrapper must have an agreeable aroma or none, since the most delicately perfumed filler ever produced may be utterly ruined by a nauseous wrapper. It must have a velvety texture, and a uniform color—not too dark nor yet too light. It must be greenish-brown rather than reddish-brown, and above all must not be coarse veined or show white markings around the veins.

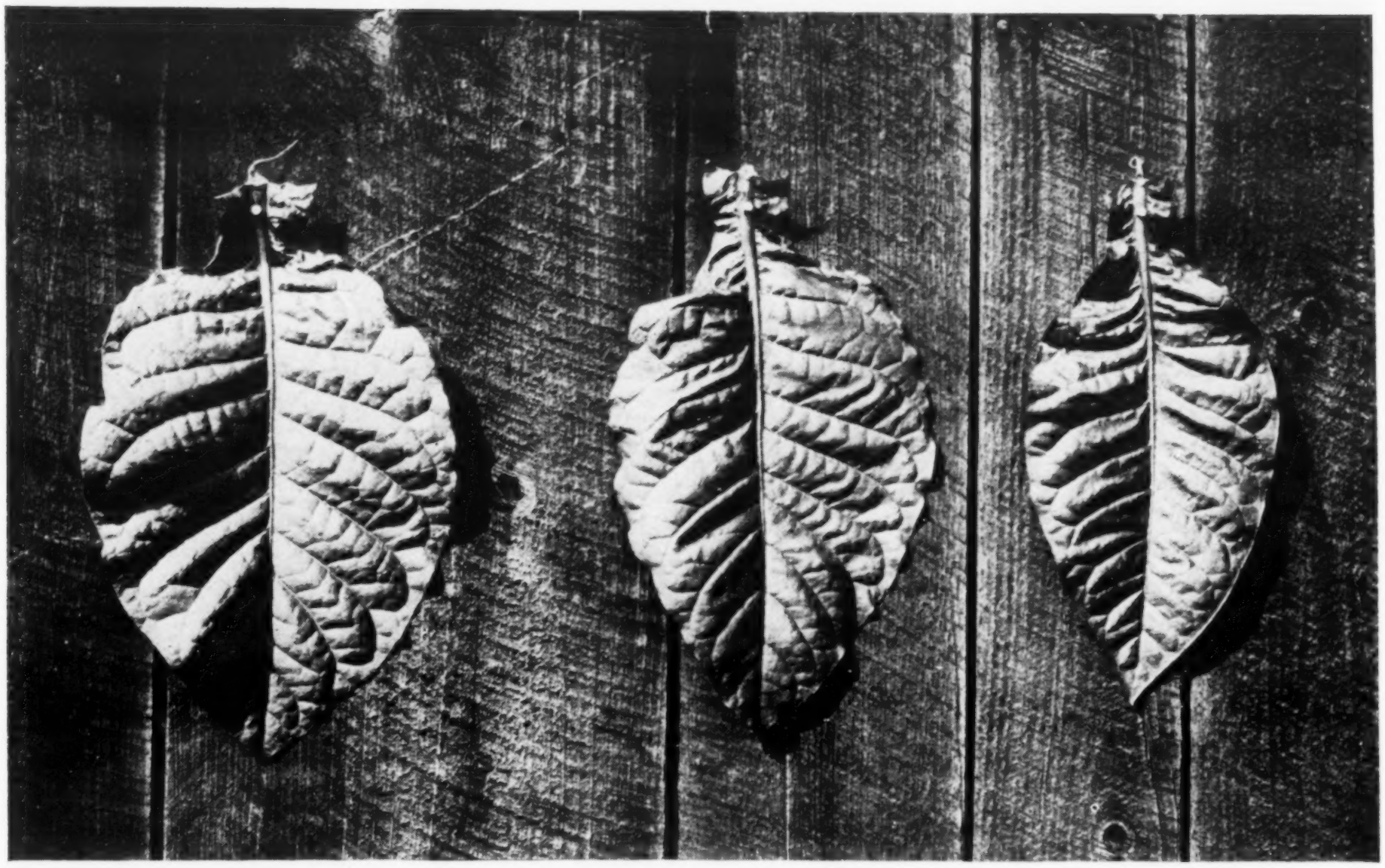
THE MANUFACTURER'S SPECIFICATIONS

So much for the demands of the consumer. Comes now the manufacturer, pressing his needs. Cigar wrappers cost money, and he must have a thin leaf covering as many cigars as possible per pound of material. The leaf should be broadly rounded at the tip, since the wrapper of finest quality comes from this portion of the blade. Again, the cigar wrapper must be strong and full of elasticity. It shaves down the profit to have a significant percentage of torn leaves come from the wrapping bench. If the purchaser breaks the wrapper in his pocket, all very well, provided he doesn't do it often enough to prevent his coming back for more; but broken leaves in the factory break the heart of the manufacturer.

THE GROWER'S DEMANDS

Finally, enter the farmer. His demands are always last to be considered, since the common practice in our national drama is to cast the farmer in the rôle of "goat" instead of giving him the star part he deserves. The grower demands a plant of quick maturity, a plant with many leaves, a plant with no lateral branches. His ideal is a strong plant standing up under wind and rain, a plant resistant to disease, one which will fill his barns to overflowing and cut down the unit growing cost.

In the narrow basin of the Connecticut river, on the land between Holyoke, Massachusetts, and Glastonbury, Connecticut, they grow the finest cigar wrappers in the United States. And this is really quite an odd fact. The two regions most famous for cigar wrappers are Sumatra and Cuba. The first is astride the Equator; the second is just south of the Tropic of Cancer. Then away up at forty-two degrees north latitude is this spot bidding fair to rival them, a p ace where soil and climate again combine to make matters right for the sovereign weed. Here some 35 000 acres are grown which bring the planters higher returns than



LEAVES OF SUMATRA TOBACCO—ONE OF THE PARENTS OF ROUND TIP

Sumatra and Cuba are the two most famous regions producing tobacço for cigar wrappers. Sumatra tobacco, while grown in the Connecticut valley, does not compete commercially with the other varieties. It, however, possesses some most desired and promising qualities, and was used as one of the parents of Round Tip. The illustration shows bottom, middle and top leaves from a Sumatra plant. (Fig. 1.)

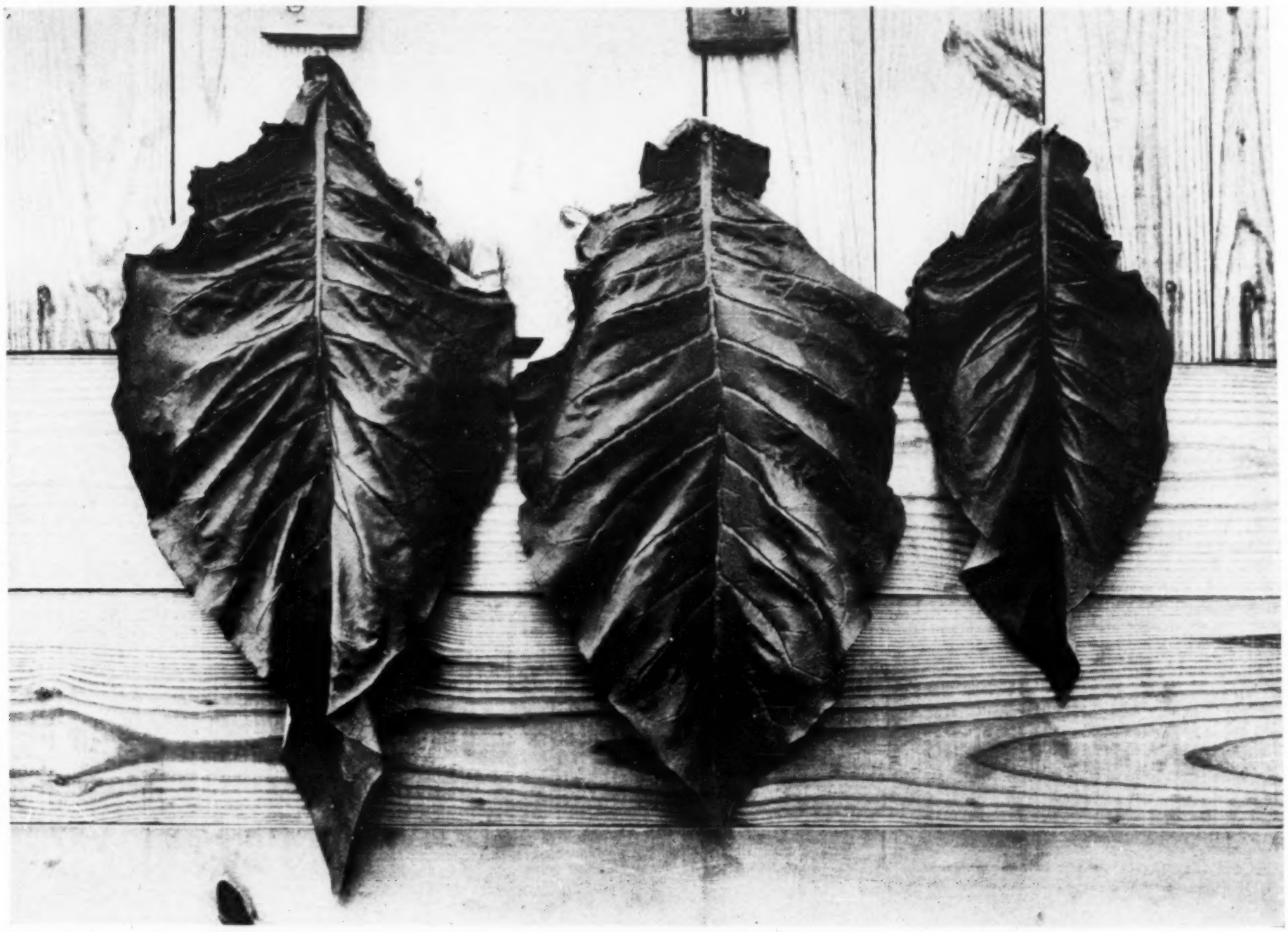
any other place of equal area on the globe.

FOUR DISTINCT VARIETIES OF TOBACCO IN THIS DISTRICT

The Connecticut valley confines its attention to three markedly different types known as Cuban, Havana seed and Broadleaf. A fourth type, Sumatra, has been tried commercially at various times, but has not been able to compete with the other varieties. It must be considered in our discussion, however, for it has certain qualities not possessed by the others.

Four tobaccos then form the basis of the nicotinous wealth of this little district. Unfortunately, like most mundane objects, each has its defects. The Sumatra wrapper leaf, though very popular with the manufacturers in this country, is small, thin and tasteless. It requires an expensive cloth-shaded field to obtain the moistur econstancy needed for proper development, and gives a comparatively low yield after all this trouble has been taken in its behalf The variety known as Cuban is somewhat similar to Sumatra and must also be grown under shade. Its somewhat larger, thicker, stronger and better flavored leaf makes it more desirable than Sumatra, but the relatively low yield and expensive equipment results in a much smaller net cash return to the farmer than he ought to have.

Sumatra and Cuban average about twenty leaves each; Havana seed and Broadleaf, which are grown without shade-cloth, have one or two leaves less. The last two are similar to each other. Just as Sumatra and Cuban form one group of tall and relatively small leafed plants, Havana seed and Broadleaf form a second group of short plants having large coarse-grained leaves. The Broadleaf blade is lance-ovate, and drooping, and is thus not well fitted for economical wrapper cutting. On the other hand, the large leaves (reaching 34 inches) when not too thick and coarse, have the finest



BROADLEAF TOBACCO—THE OTHER PARENT OF ROUND TIP

Very different are the characteristics of Broadleaf tobacco leaves as compared to Sumatra leaves shown on the opposite page. The leaves of Broadleaf are large and thick, of coarse texture and strong flavor while Sumatra leaves are small, thin and without flavor but possessing the round tips. The hybrid of the fourth generation from the crossing of these two plants is what is now called Round Tip. (Fig. 2.)

texture and flavor of all wrapper tobaccos. The Havana seed leaf is somewhat less coarse than the Broadleaf and is not quite so pointed at the tip

PRODUCING A NEW TYPE

The situation in the valley, then, has been this: Four varieties have been grown, each is imperfect in itself, but differing from each other in such a way that there was the possibility of combining the best characteristics into a single type of marked excellence. A cooperative plant breeding project was undertaken by the Connecticut Agricultural Experiment Station, Harvard University and the United States Department of Agriculture, therefore, with this object in view.

After examining the possibilities inherent in all four varieties, Sumatra and Broadleaf were selected as the two parents most promising in their qualities. The chief characteristics in which the two varieties differ, and the qualities which it was hoped might be obtained were as follows:

Broadleaf	*Sumatra*	*Prospective type*
large leaf	small leaf	large leaf
narrow tip	round tip	round tip
drooping leaf	upright leaf	upright leaf
leaves close	leaves apart	leaves close
texture coarse	texture fine	texture intermediate
leaves thick	leaves thin	leaves intermediate
flavor good but strong	flavor none	flavor intermediate
yield high	yield low	yield high

ROUND TIP TOBACCO SHOWING UNIFORMITY OF GROWTH

This new type of tobacco has produced 2,800 pounds per acre under ideal conditions as compared to about 1,500 pounds per acre from types that are commonly grown. It has a greater number of leaves, ovate in shape, thus affording a greater yield of cigar wrappers. (Fig. 3.)

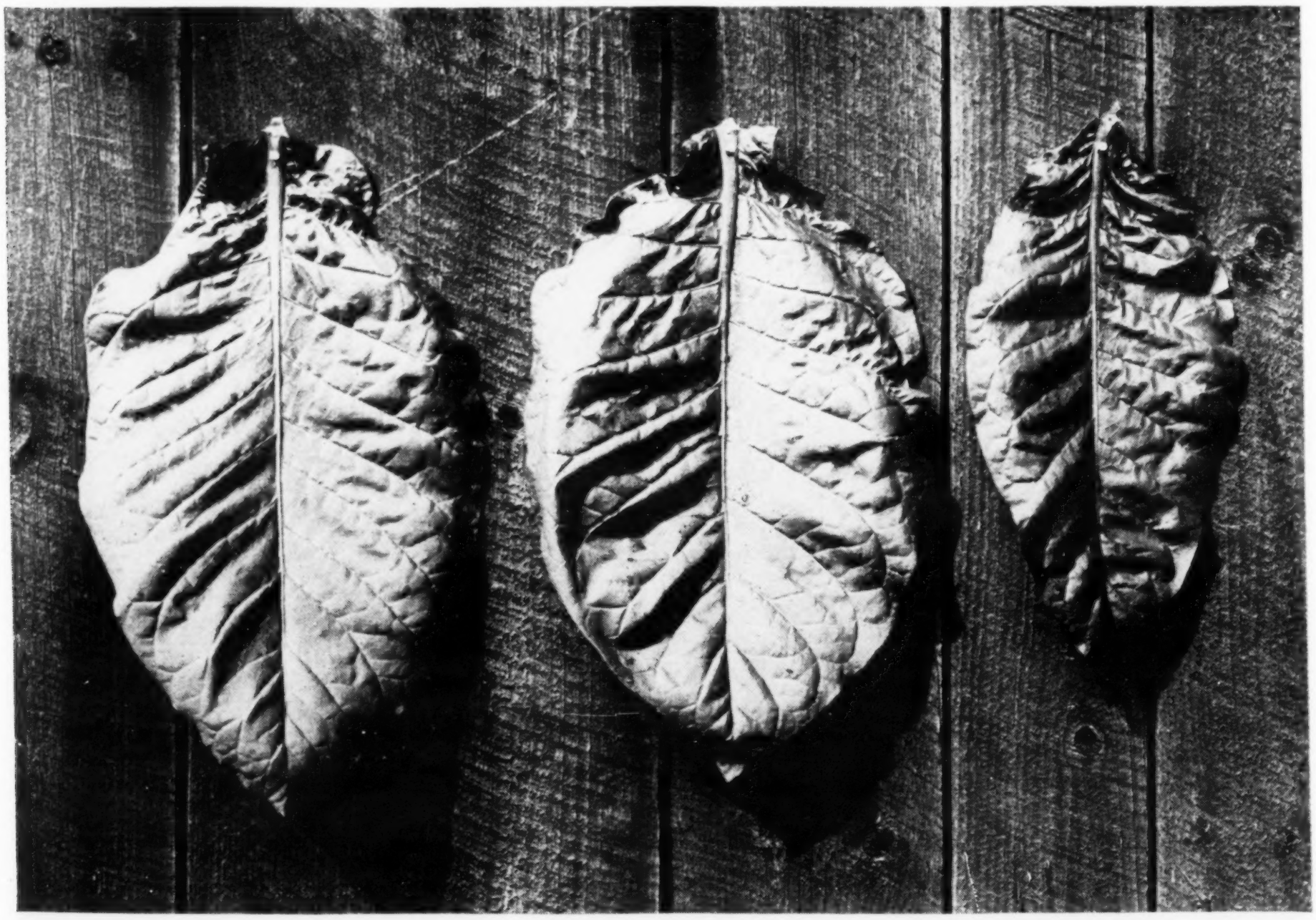
The two varieties were crossed and a small first hybrid generation grown. The plants were uniformly intermediate in type, though perhaps approaching the Sumatra rather than the Broadleaf. They grew very quickly, and apparently did not possess a very desirable root system since a slight windstorm would send them to the ground. The leaves were very coarse-veined and worthless commercially. The second hybrid generation was extremely variable, transcending the grand-parental limits in such characters as leaf numbers. Among the plants of the second hybrid were about twenty with the characteristics desired so far as one could tell from field observation. Selfed seed from these individuals was obtained, and a number of F_3 families tested. Some were variable, some were apparently constant. After careful statistical study in the field, half a dozen selections were carried to the fourth hybrid generation and further eliminations made after the leaves had been sorted and cured. The selection surviving this fine-grained seive was named the Round Tip.

QUALITIES OF THE NEW TYPE

The new tobacco possesses a leaf nearly as large as that of the Broadleaf when grown on fertile soil. Its leaves

SHOWING ROUND TIP'S GREATER RESISTANCE TO ROOT ROT

These are the roots of average plants taken from one field infected with root rot. Those on the outside are Round Tip and those on the inside Havana tobacco. The grower demanded a plant resistant to disease, and one which would stand up under wind and rain—qualities which are prominent in the new tobacco. (Fig. 4.)



ROUND TIP TOBACCO LEAVES

In comparing these leaves of the new hybrid with those of the two parents shown in Figs. 1 and 2, the immense increase in cigar wrapper surface is plainly shown. These are bottom, middle and top leaves from a Round Tip plant. Wrappers made from Round Tip leaves cannot be distinguished from the high grade Sumatra wrappers. (Fig. 5.)

are ovate instead of lanceolate, thus increasing the yield of cigar wrappers. The average leaf number is 26 instead of 19; and the leaves are upright instead of drooping, though they are not grouped together on the stalk as closely as might be desired. The strength, elasticity, grain and color of the cured article is all that could be wished. The lighter colored leaves of a greenish shade are indistinguishable from high grade Sumatra wrappers in appearance, though possessing somewhat better texture and flavor. At a meeting of tobacco growers recently, cigars wrapped with Round Tip could not be separated from cigars wrapped with Sumatra by the most distinguished tobacco experts present. The darker leaves of the brownish grades are very like imported Cuban wrappers, but in the opinion of many have a better burning quality. Crops of 2,800 pounds per acre have been secured, though these were obtained under extraordinarily good conditions. Under average growing conditions yields of about 2,000 pounds per acre may be expected. When it is realized that the types commonly grown yield only about 1,500 pounds, the increase is notable.

It remains to be seen whether a new tobacco of this kind can be introduced to such a conservative market as that to which it must be offered. But the type has now had a three year test, satisfying the requirements of some thirty planters who have grown it on considerable areas. It is as uniform in type as any of the older varieties and possesses, besides the market requirements mentioned above, some field characters which delight the grower. Not the least of these is a wonderful root system making it stand up under winds that lay other tobaccos low, and a resistance to root rot which came to it by accident rather than by design of the plant breeder. One prominent grower says of it: "If it does not largely replace other tobaccos of the Connecticut River district in the near future and add millions of dollars to our wealth, it will be because of timidness on the part of the buyers who have been taught that anything new in the tobacco trade is something to be shunned."

BREEDING EARLESS SHEEP

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In the JOURNAL OF HEREDITY, Vol. XI, No. 5, Prof. E. G. Ritzman reported that short-eared sheep, in inbreeding, have given earless offspring. This result was reported by the writer in 1918,[1] who also advanced the hypothesis that the earless sheep was the homozygote and the short-eared was the heterozygote.

The results of breeding experiments for 1920 and 1921 are as follows: One earless ram mated with normal sheep gave five offspring with short ears. One earless sheep mated with a normal ram gave one offspring with short ears. A mating earless × earless has given two earless offspring. The hypothesis that the earless sheep is the homozygote and the short-eared is the heterozygote of normal × earless mating is thus nearly proven by this result.

Short ears in sheep were formerly very common in Norway. The writer[2] has found this type in the south, in the middle and in the west of the country, and also has information that the type has spread in the north. Dr. Duré has, according to Adametz,[3] found the type in Bochara in the Karakul breed. Adametz mentioned also that Iwaneieff had seen the earless type in the same breed.

[1] Chr. Wriedt 1919. Über die Vererbung von Ohrenlänge beim Schafe. Zeitschrift für Induktive Abstammung und Vererbungslehre Band XX Pag. 262–63.

[2] Chr. Wriedt 1914. Über die kurzohrige Schafrasse Norwegens. Jahrb. f. wissenschaftliche und praktische Tierzucht IX S. 266–267.

[3] Leopold Adametz 1917. Studien über die Mendelsche Vererbung der wichtigsten Rassemerkmale der Karakulschafe bei Reinzucht und mit Rambouillets. S. 152–153.

INHERITANCE IN SWINE

JAY L. LUSH
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ONE among the many casualties of the Great War, which will not be found listed in the files of the War Department, was the stopping of a certain extensive experiment in swine breeding which was conducted at the Kansas Experiment Station under the direction of Mr. E. N. Wentworth until the spring of 1918 when the last of the persons in immediate charge of the work entered military service. That ended the taking of detailed records and the subjects of the experiment continued their growth, matured, and were marketed, so that it was impossible to resume the experiment at the point at which it stopped.

SOME VALUABLE CONCLUSIONS REACHED

However the experiment was not a complete casualty for the results already secured in four years of breeding make a few conclusions almost inescapable and point to others which can perhaps be verified, one at a time, by a few well-chosen crosses. This is particularly fortunate because there have been so few genetic experiments on swine which have gone farther than the production of a very few F_2 litters, and yet swine are very suitable for studies in heredity, not only because of their economic importance, but also because of the rapidity of their multiplication and the wide diversity of true-breeding forms and colors which they offer to the investigators.

The experiment was undertaken with the idea of securing information about the inheritance of all the well-defined characters which differed in the breeds used, but conclusions have been reached only in regard to the shape of face, set of ears, color, growth factors, and litter size. The most of the work was done on crosses of a registered Berkshire boar on registered Duroc-Jersey and Tamworth sows, but the problem of litter size was separately attacked by mating European wild boars of the Schwarzwald type to Tamworth and Berkshire sows.

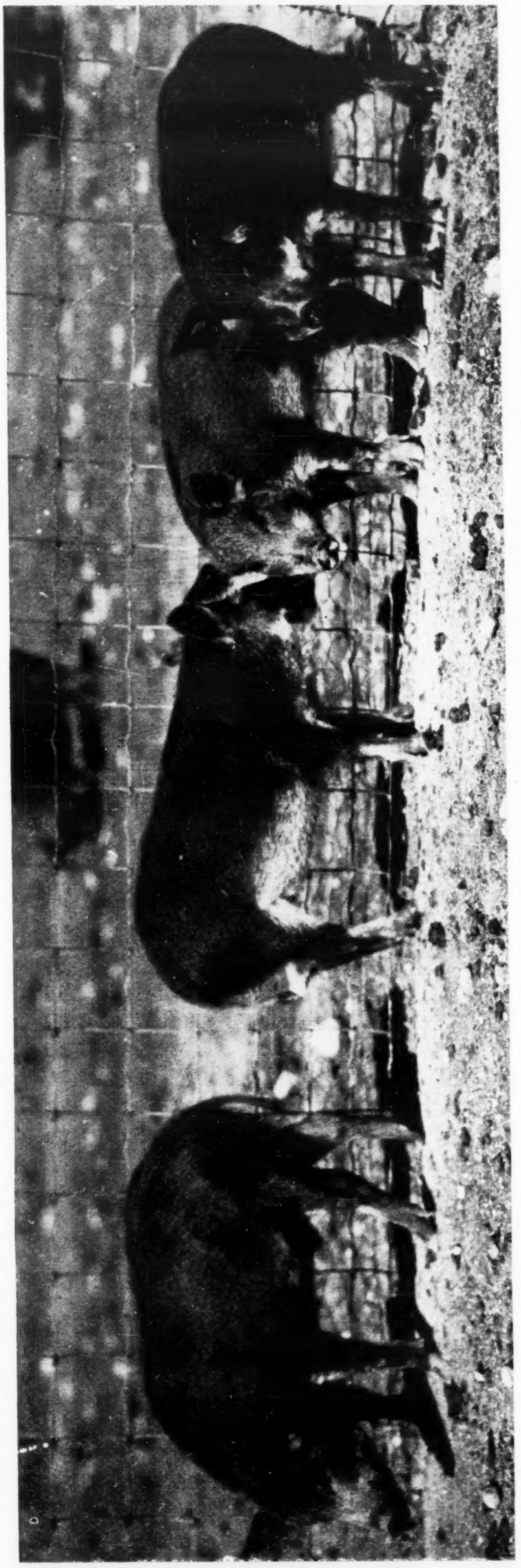
LITTER SIZE

The use of the wild boar for investigating this economically important character was originally suggested by an investigation by Wentworth and Aubel[1] in which it appeared that the distribution of the various litter sizes among ordinary domestic swine did not conform to the normal frequency curve. Since the wild hog ordinarily produces four pigs per litter, it was decided to cross a boar of this kind upon sows of one of the more prolific of the domestic breeds, such as the Tamworth which ordinarily produces about eleven pigs per litter. There were thirty-eight F_1 pigs produced in this cross, but only one of the females among them had reproduced before the experiment ended. The fact that her litter consisted of but four pigs, taken in connection with the fact that Simpson[2] reports litters of four, six, and four, respectively, from three sows of the same kind of breeding, gives an indication that the wild litter size is dominant, but tells us no more about its inheritance.

SET OF EARS

The Berkshire, Tamworth and wild hog all have erect ears of fine or moderately fine texture, and since all the pigs produced by crossing these three breeds possessed a very similar sort of ear, they throw no light upon its inheritance. The Duroc-Jersey, however, possesses a distinctly different sort of ear which is not so pointed, is of medium size, and breaks over at

[1] WENTWORTH, E. N. and AUBEL, C. E. Inheritance of Fertility in Swine. *Journal of Agricultural Research*, Vol. 5, No. 25, pp. 1145–1160.
[2] SIMPSON, Q. I. 1912. Fecundity in Swine. *Am. Breeders' Association*, Vol. 7, pp. 261-275.



SOME WEANLING PIGS FROM A WILD BOAR FATHER AND POLAND CHINA MOTHERS

The swine breeding experiments described in this article were conducted to determine the inheritance of certain well-defined characters which differed in the several breeds used, such as color, shape of face, set of ears and litter size. The economic importance of some definite knowledge regarding rate of growth as well as the greater size and vigor of the hybrids for market purposes was recognized throughout the experiments and some significant data secured. Photograph by courtesy of the Iowa Experiment Station. (Fig. 6.)

about one-third of the distance from the tip to the base, so that the outer third droops downward. There is quite a bit of variation within the breed but this is closely associated with variation in the general quality of the animal. That is, the coarser ear more than one-third broken over is usually found on the coarser, rougher animals, while the finer, more pointed ear, broken over less than one-third, is found more often on a lighter-limbed, rangy type of hog. Whether this correlation is genetic (linkage) or due simply to the mechanics of growth is not known.

The twenty-nine F_1 pigs of the Berkshire $\times$ Duroc-Jersey cross, except for one boar and one sow in the first litter (which was sired by a boar not used subsequently, and which was discarded for breeding purposes), all possessed ears which were perfectly erect but slightly larger than on Berkshires of equal size.

Only forty-two F_2 individuals were mature enough to determine definitely the shape of the ear when the work was discontinued. Of these, only one showed a typical Duroc-Jersey ear, several were intermediate, but the great majority possessed ears as erect as the Berkshire.

The F_1 boar when mated back to his dam, sired three litters totalling thirty-five pigs, nine of which had lived to be as much as six months old when the experiment ended. Of these, four had typical Duroc-Jersey ears, one was still undetermined, and four had erect ears.

The following conclusions in regard to the inheritance of the set of ear seem warranted by the data: The typical erect ear of the Berkshire is dominant by at least one and probably not more than three (F_2 ratio of forty-one erect or intermediate to one of Duroc-Jersey type) principal factors. There may be a number of minor modifying factors for size and quality as well as for the amount of breaking over. Neither breed is homozygous throughout for all the factors concerned in the

A WILD BOAR AND ONE OF HIS PROGENY FROM A DOMESTIC TAMWORTH SOW

European wild boars were used in these breeding experiments to determine the inheritance of litter size. Wild sows ordinarily produce only about four pigs per litter which is much less than is produced by sows of the domestic breeds. Tamworths farrow on the average about eleven pigs. The picture shows the wild boar used (at the right) with one of his crossbred sons. (Fig. 7.)

production of its own peculiar ear shape; i.e., being purebred is not equivalent to being homozygous in this respect.

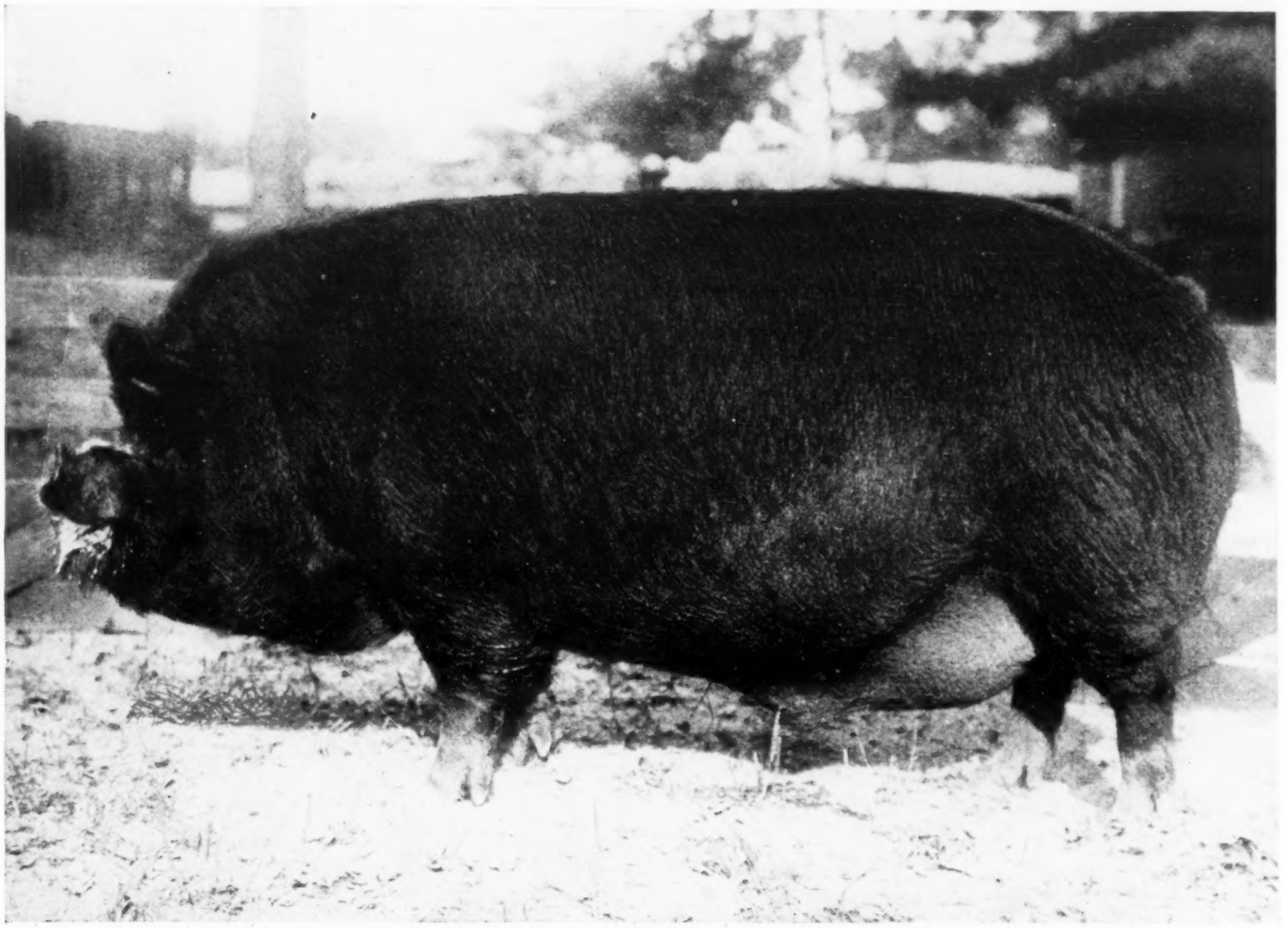
SHAPE OF FACE

This character, like the set of ear, does not complete its development until the animal is mature, and is fairly constant within each of the breeds of swine. Both the Tamworth and the wild hog are characterized by long narrow straight faces with no forehead prominence. The Wild face is the more extreme in each of these three respects, and the seven mature F_1 pigs all approach very closely to the face shape of their wild parent.

Among the common breeds of swine in America the Berkshire represents the opposite extreme to the wild hog in face shape, having a very short, extremely dished face and a forehead so broad and prominent as to give it a sort of pompadour appearance. Only two pigs from the Wild × Berkshire cross matured and both resembled the wild parent so closely that, except for color and wider foreheads, they would have been indistinguishable from the Wild × Tamworth F_1's.

Seven pigs of the F_1 generation of the Berkshire × Tamworth cross matured and could not be distinguished from the purebred Tamworths as far as face shape was concerned. This is especially surprising because Simpson[3] who crossed Tamworths and Large Yorkshires (which have a face shape similar to the Berkshire in outline although longer), reported that the result was an intermediate face shape. He does

[3] SIMPSON, Q. I. AND J. P. 1909. *Am. Breeders' Association*, Vol. 5, pp. 250-5.



A TYPICAL BERKSHIRE BOAR

In addition to the wild hog, the Berkshire, Duroc-Jersey and Tamworth breeds were used. A photograph of the registered Berkshire boar used is not now available, but the above illustration shows a typical boar of this breed. Its ears are erect like those of the Tamworth and wild breeds. Photograph from U. S. Dept. of Agriculture. (Fig. 8.)

not give the numbers for an F_2 generation and none of the F_1 individuals in this experiment reproduced, hence there is not even an indication of the number of factors responsible for the face differences in these three breeds. However the data clearly indicate this much: Tamworth long straight face is dominant over Berkshire short dished face; Yorkshire dished face forms an intermediate F_1 with Tamworth long straight face; therefore Berkshire short dished face and Yorkshire dished face must be similar phenotypes produced by somewhat different factor complexes.

The face shape of the Duroc-Jersey is intermediate to that of the breeds just discussed in that it is moderate in length and in dish, while the forehead and the hair which grows upon it usually slope smoothly upward and backward. In the F_1 generation of the Berkshire $\times$ Duroc-Jersey cross, the forehead in every case approached closely that of the Berkshire type and the face was strongly dished but not quite to the degree of the Berkshire ideal. There was some variation in dish and in length of face among the F_1s but they were all pronounced enough to be more Berkshire than Duroc-Jersey in type. In the F_2 generation very much wider variation was observed. Since no practicable means of measuring these three elements of face shape was discovered, they were simply classified according to their resemblance to one or the other of the grandparental types. Table I shows the result:

TABLE I

Character	Similar to Berkshire	Intermediate	Similar to Duroc-Jersey
Forehead Shape	37	2	3
Dish of Face	17	9	16
Length of Face	21	7	14

THE PUREBRED DUROC-JERSEY WHICH WAS THE MOTHER OF THE FIRST F_1 AND BACKCROSS GENERATIONS

The Duroc-Jersey breed possesses drooping ears in contrast to the erect ears of the other breeds used. All except two of the 29 pigs of the first generation from the Berkshire × Duroc-Jersey cross had erect ears. (Fig. 9.)

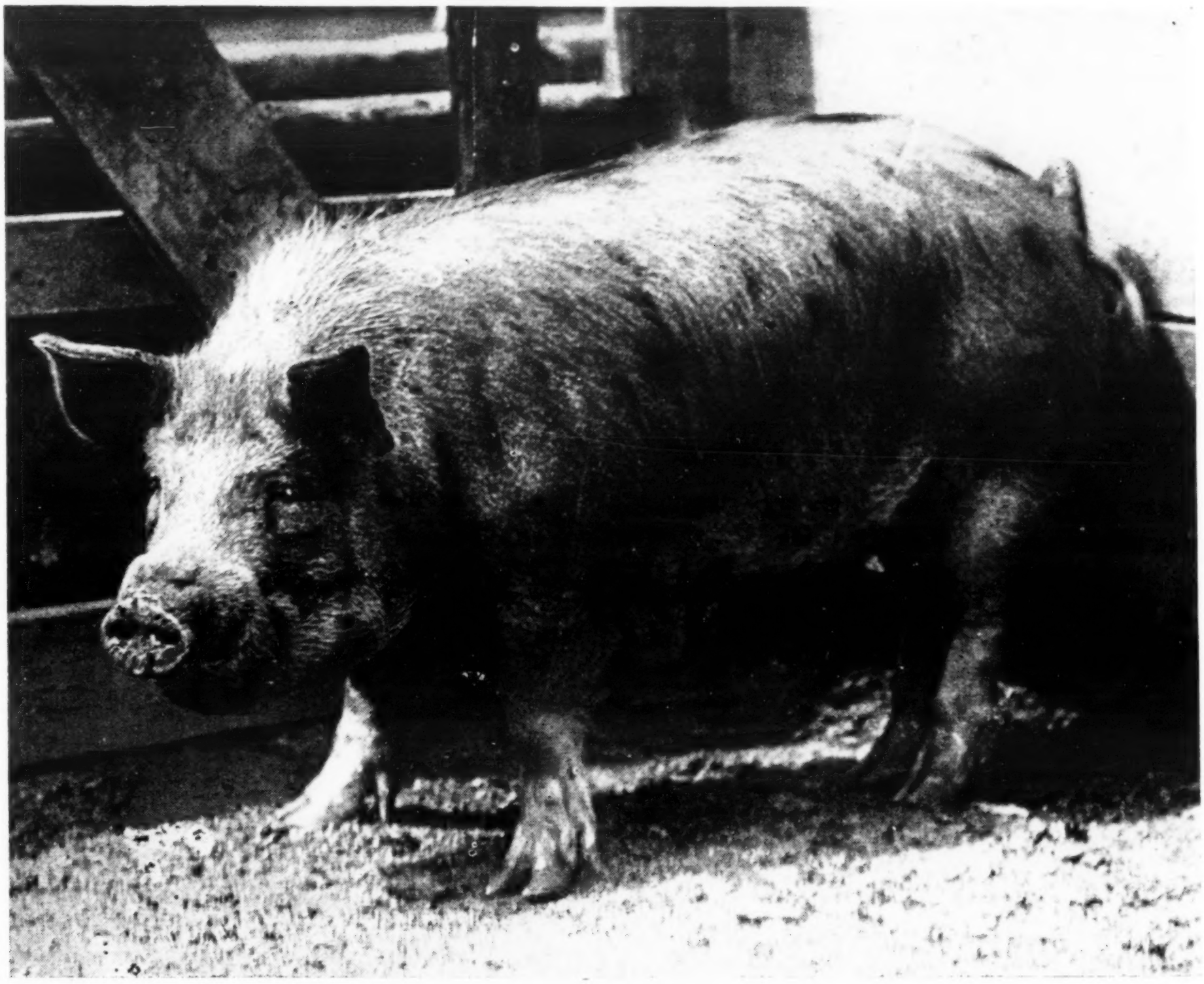
Of course it is likely that some of these groups may contain more than one phenotype, since the characters are not definitely measurable ones, but the variation from one extreme to the other was by no means continuous and the investigators believe that the number of phenotypes which result from this cross is quite limited. There was some evidence of correlation between length of face and dish of face because hogs with both extremely dished faces and extremely long faces did not occur, but on the other hand, short-faced hogs occurred with both extremely dished and extremely straight faces. This probably means that such correlation as may exist is developmental or anatomical rather than genetic (linkage).

Other conclusions which may be drawn with respect to face shape are these: Several factors differing in importance and in degree of dominance are responsible for the anatomical differences which have been considered under the title of face shape. Certain of these factors affect certain parts of the face much more than they do other parts. The number of these factors can not be so very large, else the parental types would not have been recovered among such limited numbers.

SWINE COLOR

The carefully controlled experiments on swine which throw any light upon the inheritance of the various colors are not numerous and the resulting interpretations which are established beyond any scientific doubt are few indeed. The whole subject has been reviewed recently in the *Journal of Heredity* by Wright[4] and, as far as the author knows, since then there has been only one notable addition to the literature upon the subject;[5] therefore what seems most likely to be the truth about the inheritance of the different colors found in swine will be very briefly summed up as follows:

[4] Wright, Sewall. 1918. Color Inheritance in Swine. Journal of Heredity, Vol. 9, pp. 33-38.
[5] Lloyd-Jones and Evvard. Iowa Agricultural Experiment Station, *Research Bulletin*, No. 53.



A CROSSBRED FROM THE BERKSHIRE × DUROC-JERSEY CROSS

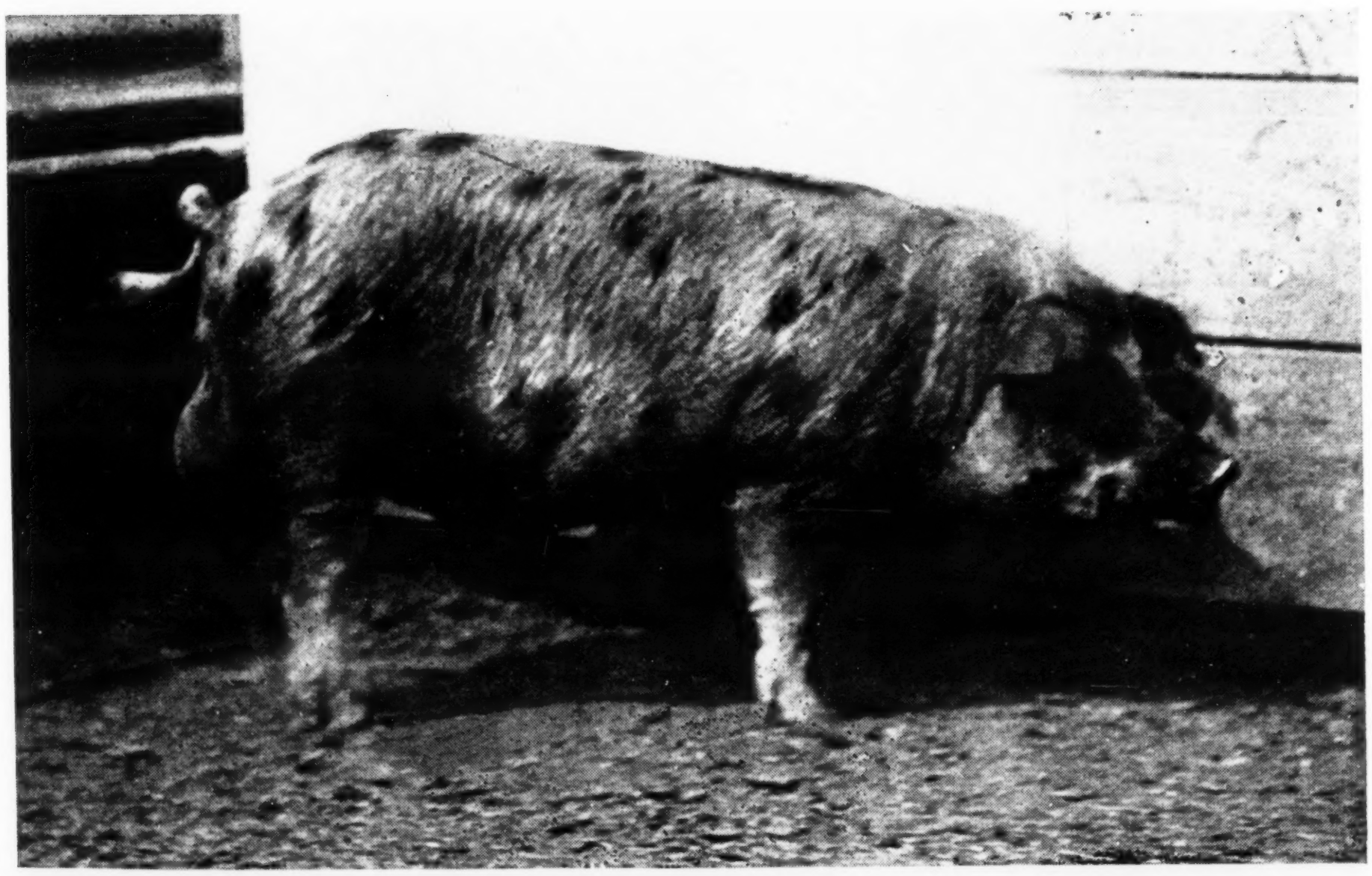
This boar was the father of the second and backcross generations. Compare it with its parent breeds shown in Figs. 8 and 9 and note its color, erect ears and intermediate face shape. (Fig. 10.)

White: There are at least three kinds of white which are genetically distinct. Self white is dominant over all other colors with which it has been crossed and is probably dependent upon only one factor. White belt (as seen in the American Hampshire or in the German Hanoverian swine) is usually dominant but must depend upon at least two factors since belted offspring sometimes result from non-belted parents. The white which is best illustrated in the "six white points" of the Berkshire or Poland-China, seems to be an extremely diluted red or the absence of all shades of red. The author has found no record of true albinism in swine.

Black: There are certainly two and very probably three kinds of black. Self black (as in the English Large Black swine) is reported dominant to Tamworth red. The black which is associated with the white belt in the American Hampshire is dominant to Duroc-Jersey red and depends upon a single factor. There is no evidence as to whether these two kinds of black are genetically distinct, or the latter is merely self black plus the additional unknown factors for white belt. The black of the Berkshire and Poland-China is certainly distinct from both the preceding kinds since it always breaks up, when crossed with red, into numerous black spots scattered over a lighter background, usually red or sandy but sometimes white.[6] This black, as will appear from the results of this experiment, is caused by a

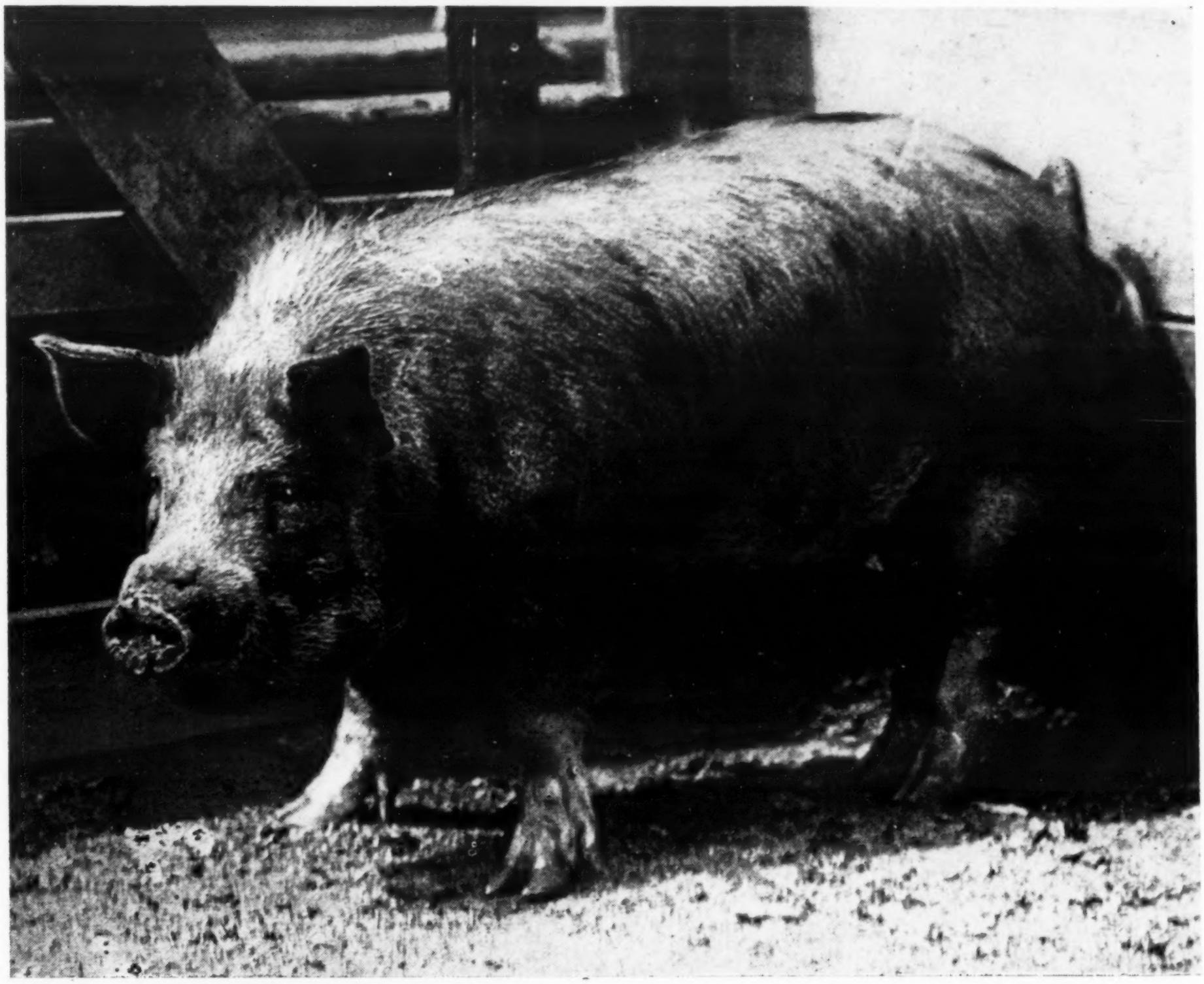
[6] Severson, B. O. 1917. Color Inheritance in Swine. Journal of Heredity, Vol. 8, p. 379.

A BERKSHIRE X DUROC-JERSEY CROSS SHOWING A SHORT STRAIGHT FACE (Fig. 11)



ANOTHER BERKSHIRE X DUROC-JERSEY CROSS

This is a first generation boar with drooping ears—one of the two out of the 29 first generation pigs which did not have erect ears. (Fig. 12.)



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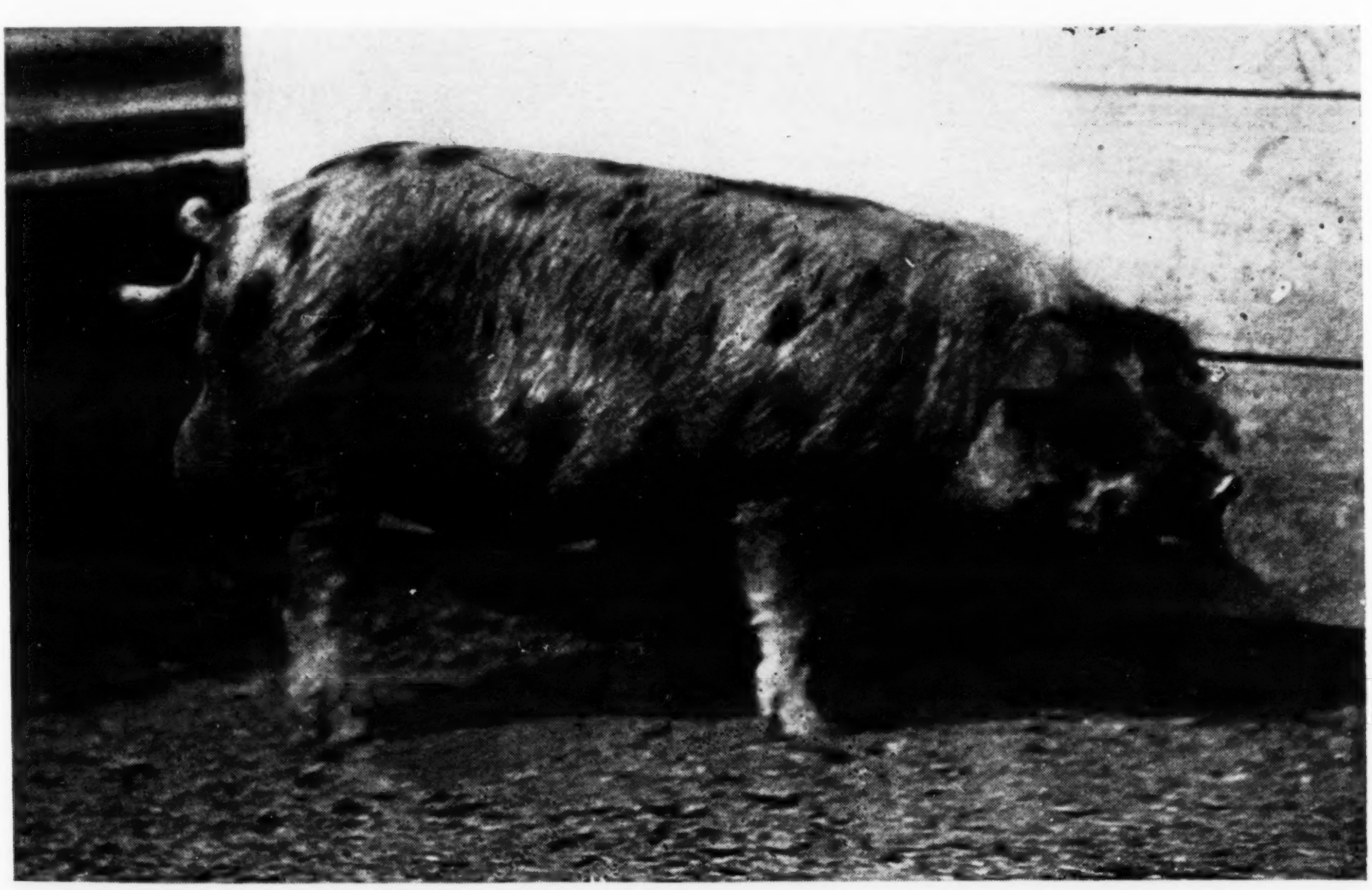

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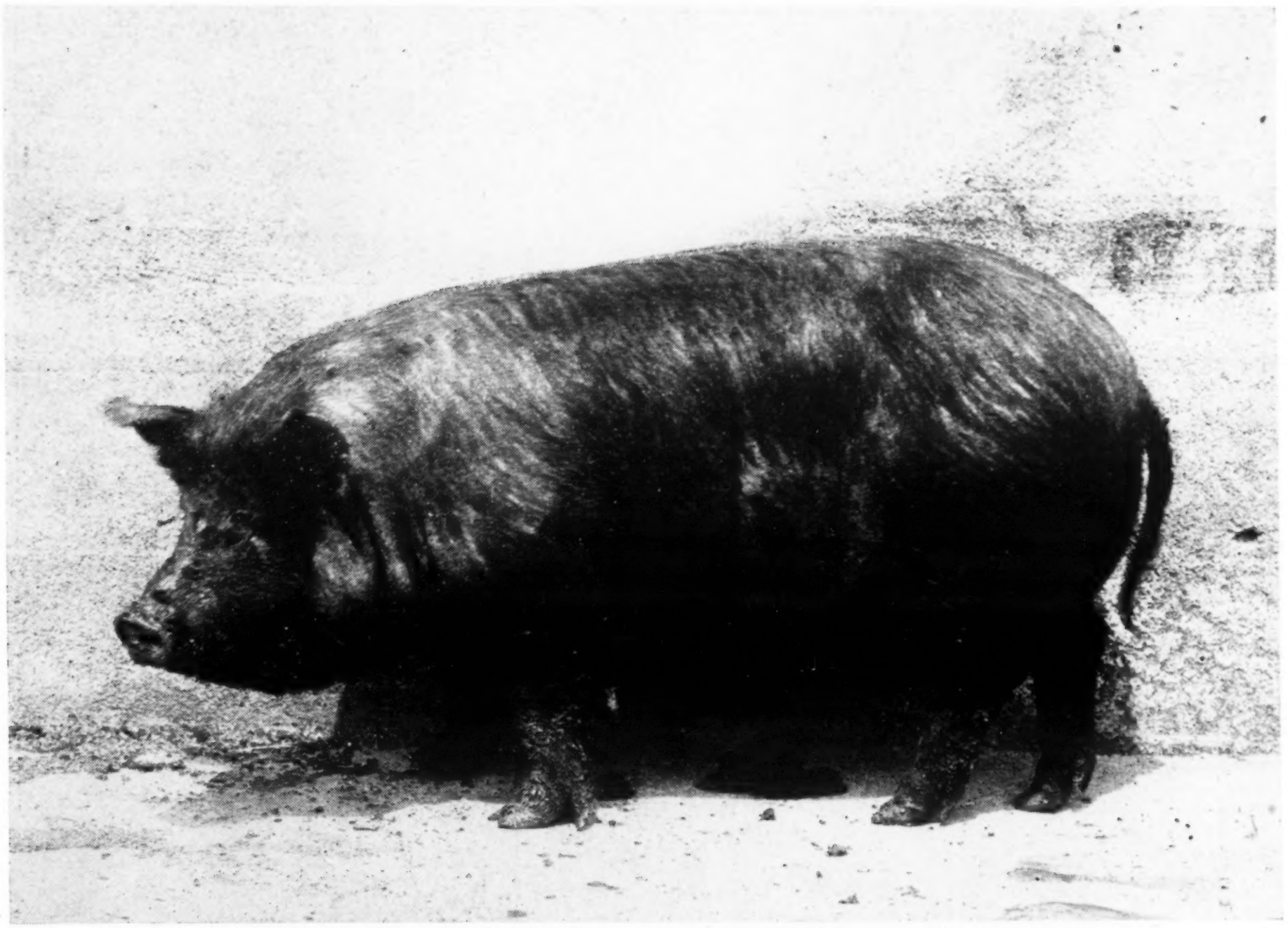


A SECOND GENERATION BERKSHIRE X DUROC-JERSEY CROSS

An illustration of the appearance of the Berkshire type of forehead in the second generation. Contrast with the different type shown in the following figure. (Fig. 13.)

single factor which alone produces black spots irregularly scattered over a lighter ground color and, when extended by the action of various modifying factors, it covers all the body except the "six white points." Reasoning from the similarity in appearance and ancestry rather than from any definite experimental data, the Spotted Poland-China possesses the same fundamental factor for black spots but many of the factors which influence the size of those spots are absent.

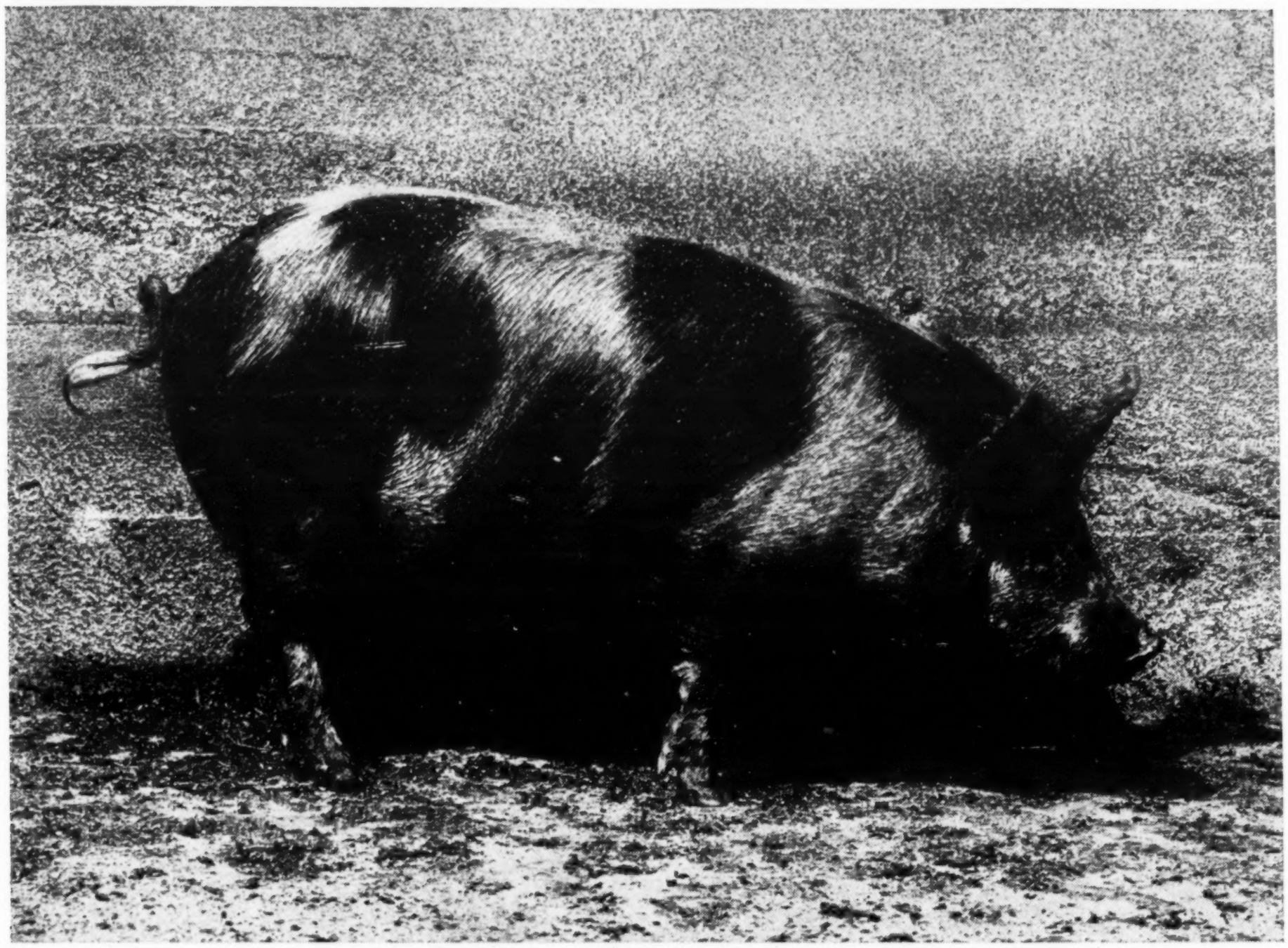
Red: Two kinds of self red are genetically distinguishable by their behavior toward self white. Possibly the factors which affect the white are distinct from the factors for red. Differences in the intensity of the red seem to be inherited but there are no experimental data to back up that popular opinion.

Roaning: Appears quite frequently among the descendants of self whites by self reds, or of self whites by belted blacks. Often it is not apparent at birth but develops later.

Immature Striping and Adult Agouti of the Wild Hog: This pattern is dominant over all other co'ors except self white and the white belt, but the dominance is not always complete.

COLOR RESULTS FROM THIS EXPERIMENT

The European wild hog is of a color corresponding very closely to the agouti or gray pattern common among many other wild mammals, except that in this case it is an uncommonly dark slaty shade. Another interesting feature is that the young are born with longitudinal stripes about a centimeter wide running the full length of their bodies and extending over all the back and sides, but with very light bellies. This is quite evidently a protective coloration for at a short distance they blend in very well with the sticks and trash on the ground. The contrasting

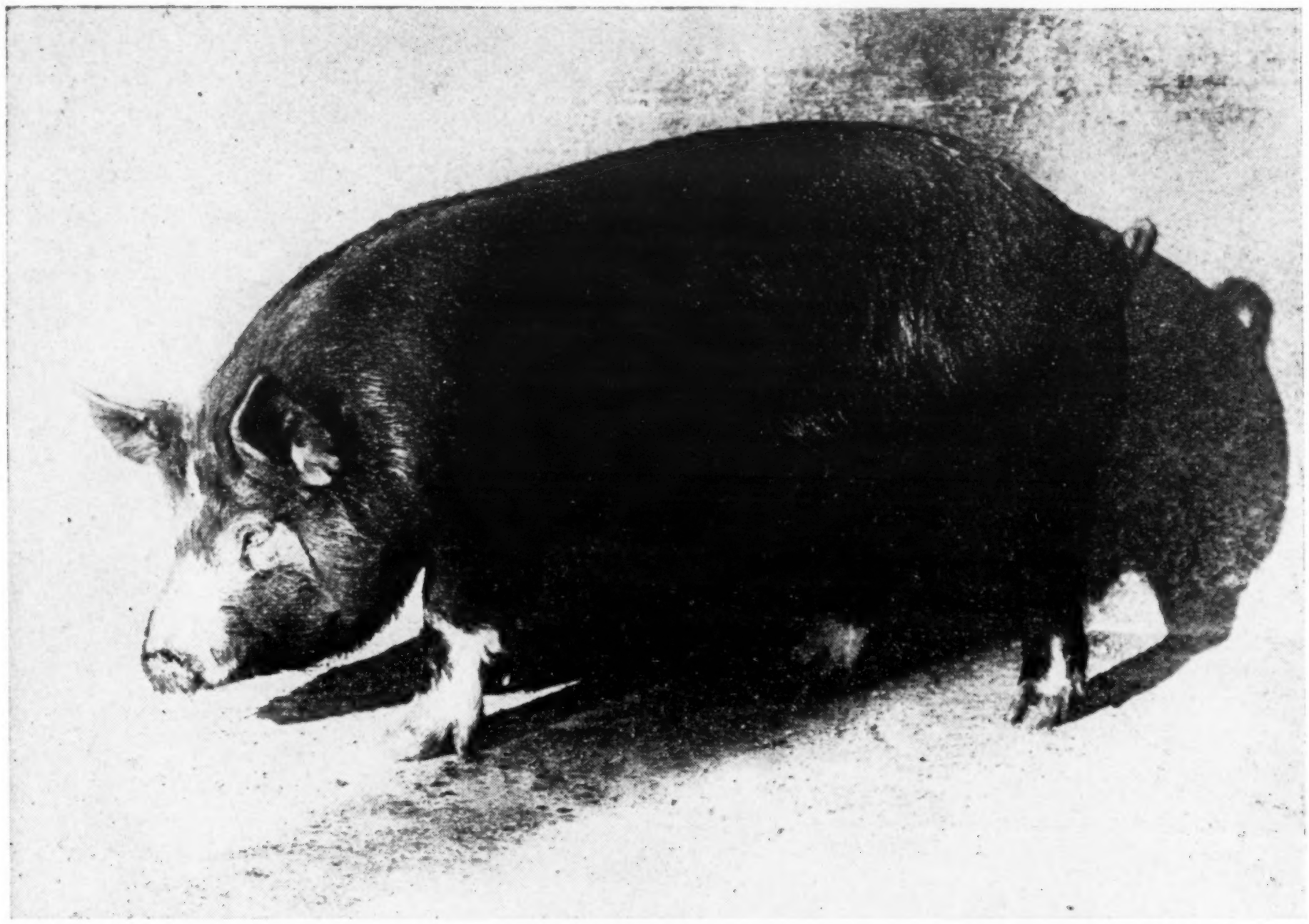


A BERKSHIRE X DUROC-JERSEY CROSS

An example of the re-appearance in the second generation (Berkshire × Duroc-Jersey) of a long straight face similar to that of the Duroc-Jersey. The first cross was closer to the Berkshire than to the Duroc-Jersey in length and dish of face and shape of forehead. Various combinations segregated out in the second generation. (Fig. 14.)

stripes were brown and sandy on all the thirty-eight pigs produced by crossing the wild boars upon purebred Tamworth sows. They were quite uniform in color. However, on the seventeen pigs produced by crossing the wild boars on purebred Berkshire sows, the bellies and light stripes were a very light sandy, almost white, and the darker stripes were a darker brown; that is, there was less of a reddish tinge throughout and, in addition, there were large black spots scattered all along the whole under surface. This is most readily interpreted as meaning that the wild pattern is not completely epistatic but lets the Berkshire black spots develop along the underline and allows the Tamworth red to show up in the reddish tinge of the offspring from that cross.

Four F_2 pigs, all striped but of different belly colors, were produced in the Wild × Tamworth cross. One had a very light, almost white, belly (presumably lacking the Tamworth factor or factors for red), two were like the F_1s, and one was like the F_1s except that it had some large black spots in both hair and skin scattered along its belly. There was one backcross litter by an F_1 boar of a purebred Tamworth sow. Three of these were faintly striped and possessed small black spots on their bodies, two were like the F_1s, two were red with small black spots, and one was self red. This seems to mean at least two independent factors —one for black spots and one for the striping pattern—and another factor for intensity of the striping which may be linked to the factor for black spots.



THE SECOND GENERATION PIG WHICH SHOWED THE MOST BLACK (BERKSHIRE X DUROC-JERSEY CROSS)

The first generation was composed wholly of red pigs with black spots. There was much variation in the second generation of which the case illustrated above is an extreme example. (Fig. 15.)

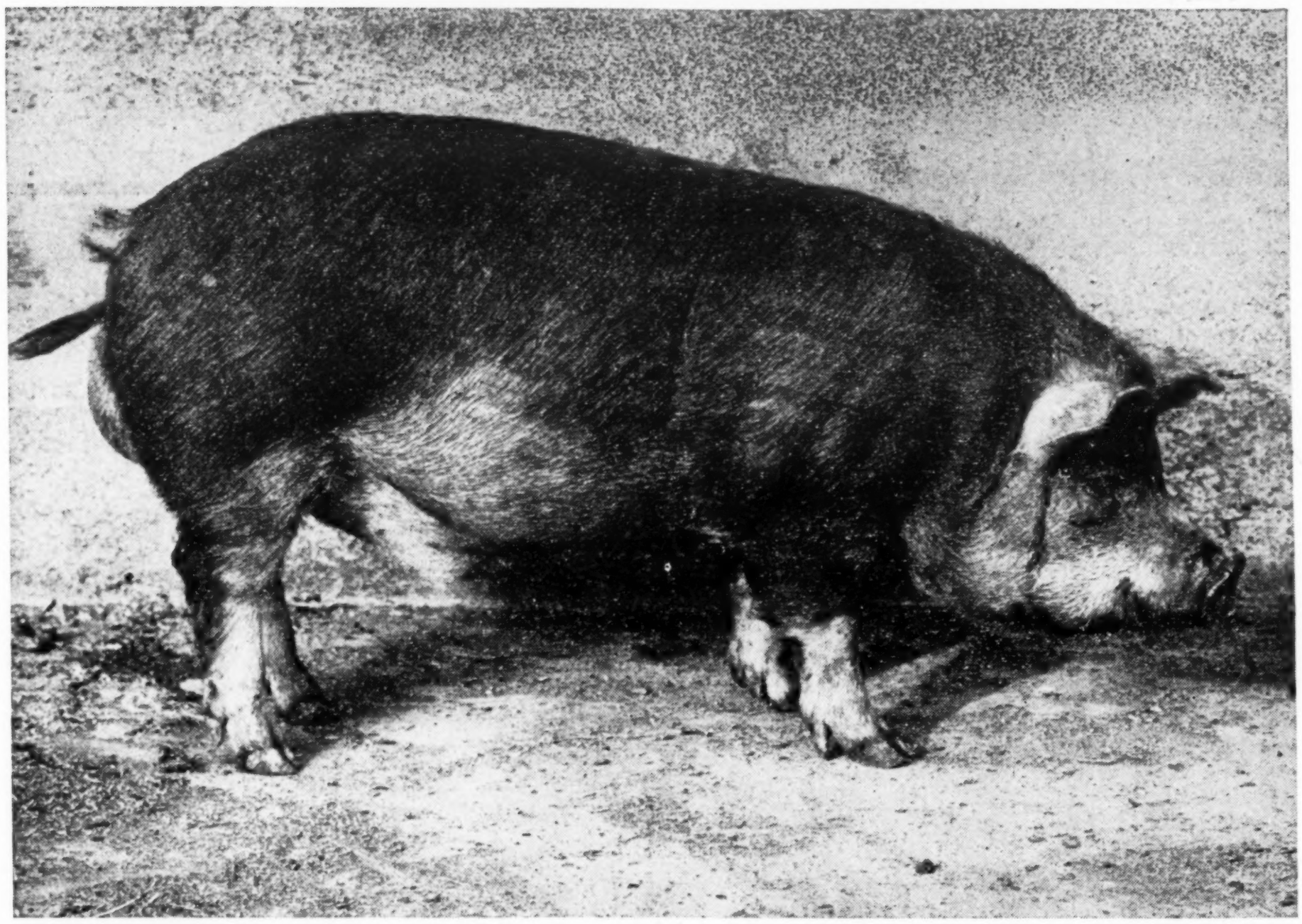
Ten pigs were produced in the F_1 of the Berkshire×Tamworth cross. Eight were red with one or more small black spots and two were self red. The spots were very small and much fewer than in the pigs from the Berkshire×Duroc-Jersey cross. One had but a single black spot and it seems possible that the restriction factors for black are so strong in the Tamworth breed that the two self red pigs are merely somatic variations in the amount of black and not genetically different from their litter mates.

In the Berkshire×Duroc-Jersey cross there were produced an F_1 generation of twenty-nine pigs, an F_2 generation of one hundred fifty-one pigs, a backcross generation (F_1♂ × Duroc♀) of thirty-five pigs, one F_3 litter of eleven pigs, and a litter (F_1♂ × F_2♀) of five pigs. The F_1 pigs were all red with black spots, but the red became lighter in color as they grew older. The colors of the F_2 and backcross pigs are given in Table II.

TABLE II

Color	F_2	Backcross
Black-and-red	47	19
Black-red-and-sandy	10	.....
Black-red-and-white	10	1
Black-and-sandy	11	.....
Black-sandy-and-white	6	.....
Black-and-white	27	.....
Self Red	14	14
Red-and-sandy	3	1
Red-and-white	3	.....
Self Sandy	7	.....
Sandy-and-white	7	.....
White	3	.....
Totals	148	35

The red and sandy are quite distinct at birth but as the pigs grow older they may become darker or lighter until at maturity almost all shades of red are represented. Taking the classification at birth, it appears that black con-



A RED BOAR OF THE SECOND GENERATION OF BERKSHIRE X DUROC-JERSEY CROSS

This boar was lighter colored on the belly than on its sides. The presence of two shades of red on the same animal was characteristic of nearly one-fourth of the second generation. Compare with the nearly solid black pig shown on the opposite page. (Fig. 16.)

trasted with the absence of black gives a perfect 3 : 1 ratio in F_2 and a close approximation to a 1 : 1 ratio in the backcross. Therefore it seems proven beyond doubt that the Berkshire possesses a single factor for black spots which is absent from the Duroc-Jersey and the Tamworth. The size and

TABLE III

Description	F_2		Backcross	
	Calculated	Observed	Calculated	Observed
Black-and-red Black-red-and-sandy Black-red-and-white	62.4	67	17.5	20
Black-and-sandy Black-sandy-and-white	20.8	17		
Black-and-white	27.7	27		
Red Red-and-sandy Red-and-white	20.8	20	17.5	15
Sandy Sandy-and-white	13.9	14		
White	2.3	3		
Total	148	148	35	35

A LITTER OF THE SECOND GENERATION SHOWING VARIATION IN SIZE

The second generation was distinctly more variable than the first. (See the graphs in Fig. 19.) This would be expected if there is segregation of growth factors. The weights of these hogs, from left to right, were 221, 293, 90, and 170 pounds (Fig. 17.)

number of the spots is largely determined by modifying factors which must be numerous since no pig in F_2 possessed as much black as a pure bred Berkshire, although one had about ninety-five per cent as much. Those which have red color upon them as contrasted with those which have no darker shade of red than sandy, constitute almost exactly nine-sixteenths of F_2 and fully 100% of the backcross. Therefore it is reasonably clear that the Duroc-Jersey possesses two factors, absent in the Berkshire, which are both necessary for the production of red. If we assume that either factor by itself produces some shade of sandy, everything is satisfactorily explained except that the pigs carrying black have a much higher proportion of those which lack both red and sandy than do the pigs which do not possess the black. If we assume a factor linked to black which can dilute to white the sandy produced by one of the factors for red when the other factor for red is absent, the actual results are very close to the theoretical ones. This is shown in Table III.

The author has no theory to account for the presence of two shades of red on the same animal. The fact that these "bicolor reds" constituted a most exactly one-fourth of the F_2 generation seems to point to a simple explanation, but there were three easily distinguishable types of this bicolor character, as follows: first, roaning, of which the genetic foundation is not known; second, small irregular spots of red, usually around the face, particularly on the eyelids, while the rest of the animal was some lighter color; and third, a lighter colored belly than sides or back. This last feature is always found as an integral part of the agouti pattern where that occurs among other mammals and seems to be connected with that pattern here also, for it is very prominent on the young of the wild hog, and when an F_2 boar which was red with a sandy belly was mated to an F_2 sow (both from the Berkshire × Duroc-Jersey cross), which was white but had

A LITTER OF THE THIRD GENERATION (BERKSHIRE X DUROC-JERSEY CROSS)

Showing striped pigs with lighter colored bellies. This striping is a curious atavistic recurrence of an ancestral trait present in the wild boar but not in the domestic breeds. The recurrence here is doubtless due to a recombination of Mendelian factors. (Fig. 18.)

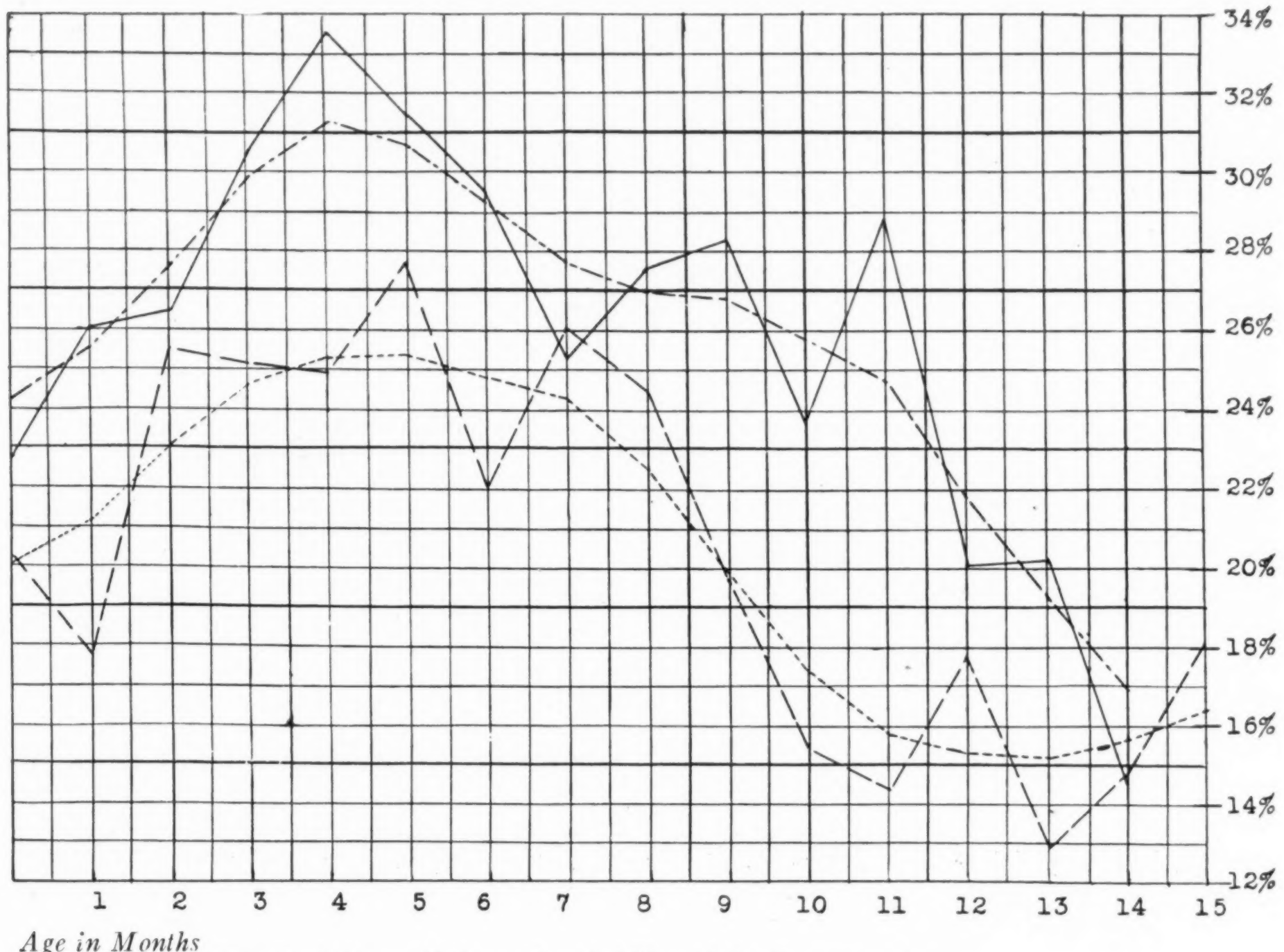
black pigment patches in her skin, there resulted an F_3 litter of eleven pigs *every one of which* had a lighter belly than back and was striped in a fashion similar to that of the young of the wild boar but differing from the latter in the shade of the contrasting stripes. They were not uniform in shade themselves. This type of "reversion" in swine has been reported frequently, but the remarkable fact that so large a litter as this should so uniformly show both the lighter belly and the striping pattern makes it seem certain that the factorial basis for this "reversion" is simple, and that both lighter belly and striping are produced by almost identical factor complexes. Two individuals of the F_2 generation showed stripes similar in pattern but very faint.

DIFFERENCES IN GROWTH

The economic importance of some definite knowledge in regard to factors for rapid growth may be surmised from the extent of the practice of cross-breeding hogs in order to secure the greater size and vigor of the F_1 hogs for market purposes. The Berkshire × Duroc-Jersey cross was extensive enough to furnish significant data upon this point. Since they were not all born at the same season nor in the same year it is obvious that they were not all exposed to identical weather conditions nor fed rations as identical as would be desirable in a nutrition experiment. However it was the aim always to feed the best possible ration to produce the maximum practical gains and it is believed that the data are, on the whole, reasonably comparable. The pigs were weighed at birth and at monthly intervals afterward and the coefficients of variation of the weights of the F_1 individuals for each month were figured separately from those of the F_2 individuals. The resulting curves are shown in the accompanying figure.

The outstanding fact of genetic importance is that the variability of the F_2 generation is distinctly greater than that of the F_1. That, to be sure, is

The Coefficients of Variability for the Monthly Weights of the F_1 and F_2 Generations of the Berkshire X Duroc-Jersey Cross



— — — — — Graph of the coefficient of variability of the F_1 generation.
---------- Smoothed curve for the C. V. of F_1.
———————— Graph of the coefficients of variability of the F_2 generation.
—-—-—-—-— Smoothed curve for the C. V. of F_2. (Fig. 19.)

what was to be expected from the genetic standpoint and it is in agreement with the experience of practical breeders. It is definite proof of two things: First, that some of the factors which have the power to stimulate growth are not identical in the Duroc-Jersey and the Berkshire breeds; second, that there is some degree of homozygosis for these growth-stimulating factors within the limits of each breed.

To what extent being purebred from the standpoint of the breed registry society indicates homozygosis for these factors; whether the number of factors involved can be determined; whether the differences in growth indicate differences in the identity of these factors or merely differences in the combinations; and whether these factors are so linked in groups as to make recombination of the desirable ones impossible or at least impracticable; these are all interesting questions which these data raise but are too meager to answer.

Other interesting questions, not primarily genetic, relate to the shape of the curve. The maximum variability seems to be reached at or shortly following weaning time and coincides with the period of the lowest mortality. Does this mean that the best time to select breeding stock for size and early maturity is when they are from three to six months old? Of course it was impractical to keep the hogs which were not desired for breeding purposes until they were two or three years old and therefore the question is still left open as to whether the hogs finally would not have become more uniform in size; that is, whether the differences were in potential size or in earliness of maturity.

Figure 17 is a photograph of one of the F_2 litters most extreme in its range of variation in growthiness. These four individuals had received identical treatment and none of them had ever been noticed to be sick, yet when this picture was taken when they were being marketed at the age of eleven months the weights were, from left to right: 221, 293, 90, and 170 lbs.! Possibly more animals are born runts than is commonly believed.

CONCLUSION

It is not believed that all the hypotheses which have been tentatively advanced in this article will stand in every detail without amendment the test of further research. However some of them will and if the others awaken enough interest to stimulate further research with this economically important animal, they will have served a useful purpose.

POSTSCRIPT

Since the above was written a report[7] of the results of a cross between mule-foot and Duroc-Jersey swine has been published which agrees closely with two of the main conclusions reached in this experiment: Namely, that the presence of black as contrasted to its absence is dependent upon a single factor and that the different shades of red are due to the interaction of a few independent factors which do not affect black. The black of the mule-foot swine behaves like that of the American Hampshire but whether the two are genetically identical is still undetermined.

Castle's Book Revised

GENETICS AND EUGENICS: A Textbook for Students of Biology and a Reference Book for Animal and Plant Breeders, by W. E. Castle, Professor of Zoology in Harvard University and Research Associate of the Carnegie Institution of Washington. Harvard University Press 1920. 395 pages, 154 figures.

Its clearness and pleasing style as well as its thoroughness of treatment have made Professor Castle's "Genetics and Eugenics" one of the most extensively used books on its subject since its appearance in 1916. In the second edition, which has recently appeared, several chapters have been rewritten and the total length has been increased by 42 pages in order to take account of the rapid progress of our knowledge. The subjects of linkage and the nature of genetic change are dealt with at considerably greater length.

The greatest change in viewpoint is with respect to the hereditary basis of fluctuating variation. In his earlier work, Professor Castle assumed that adult characteristics depend on relatively few mendelizing unit factors, and accounted for his success in bringing about great changes, by means of long continued selection of minute variations, by holding that the hereditary factors are themselves subject to fluctuating variation. His own experiments, however, as well as others, stimulated to a large extent by his championship of the above view, have now demonstrated beyond question the remarkably high degree of constancy of most Mendelian factors, and have made it clear that each characteristic is in general affected by many factors. Fluctuating variation is thus interpreted in the present edition as depending largely on the recombinations possible in a system of many unit factors, each insignificant in its own effects, and to a much less extent upon mutation of the units themselves.

Taken as a whole, the book can be heartily recommended as giving a reliable and very readable account of the present state of knowledge of genetics together with a sane discussion of the application to eugenics.—S. W.

[7] Detlefsen, J. A. and Carmichael, W. J. Inheritance of Syndactylism, Black, and Dilution in Swine. Journal of Agricultural Research, Vol. 20, pp. 595-604.

ORIGIN AND DEVELOPMENT OF THE NERVOUS SYSTEM[1]

A Review

SEWALL WRIGHT
Bureau of Animal Industry, U. S. Department of Agriculture

THE subject of Professor Child's latest book is of wider interest than might be thought from the title, dealing as it does with some of the most fundamental problems in biology.

THREE FUNDAMENTAL PROBLEMS

The means by which the parts of an organism are coordinated, making it an individual, instead of merely a mass of living matter, is one of these problems. Three modes of interaction between parts of the body are recognized: mechanical stress, transportation of internal secretions in a circulatory system, and transmission of stimuli directly through the protoplasm as in the nervous system of animals. In spite of the great emphasis which recent discoveries have placed on the regulatory action of internal secretions, most biologists will doubtless agree with Child in considering the nervous system as the most important source of internal coordination, as it undoubtedly is of external adaptation.

No less fundamental is the problem as to the agency which controls the course of development. The orderly series of processes—cell divisions, formation of cell layers, formation of organs by differential growth and complicated foldings, qualitative differentiation into epithelium, nerve, muscle, gland, bone, etc., all in proper functional relations—through which, in the course of a few weeks, a single, apparently rather simple, microscopical cell converts itself into a highly complex multicellular organism, has been the despair of those who have attempted to explain life phenomena in terms of physics and chemistry.

DEVELOPMENT IN RESPONSE TO EXTERNAL STIMULI

Child emphatically rejects the extreme preformist view, under which development consists in the growth and assembling of parts already represented in the egg cell by determiners, and takes place without regard to external conditions so long as the latter are not incompatible with life. He finds the coordinating agency of development in the same property of living protoplasm of transmitting stimuli which finds its highest development in nerve cells. Development, under this view, is ultimately a reaction to external stimuli.

The action of a stimulus on the egg cell sets up a temporary excitation-transmission pattern. Excitation means higher metabolism, a higher rate of living. The excitation-transmission pattern thus means a metabolic gradient in the egg. Owing to differential behavior of the protoplasm at different rates of metabolism, the prevailing excitation-transmission pattern tends to be accompanied by material differentiation, such as holds between the yolk-laden, slowly dividing vegetative pole, and the yolk-free, actively dividing animal pole of the egg. This primary "organismic pattern" may have symmetry of various sorts; spherical, simple axial, or bilateral, depending on the pattern of action of the external stimuli, which reach the egg. As cell division proceeds, coordination is maintained by continuance of the primary metabolic gradient, now to some extent independent of the continued play of external stimuli, owing to the material differentation at different levels. The general plan of the

[1] *The Origin and Development of the Nervous System*, by Charles Manning Child, Professor of Zoology University of Chicago. The University of Chicago Press 1921. 296 pages with 70 figures. Price $1.90 postpaid.

developing organism is determined by the type of symmetry in the gradient pattern.

COMPLEXITY IN DEVELOPMENT

As the hereditary potentialities of all cells of a given organism are believed to remain the same, it may seem difficult to understand how a merely quantitative gradient can bring out the complexity of structure and the qualitative differentiation of tissues, which make their appearance. The hereditary constitution, however, is necessarily complex. Different elements in it may prevail at different rates of metabolism. Moreover, the gradient pattern while continuous is ever changing. The past history of cells is thus a factor limiting their later development, in addition to genetic constitution, position in the gradient pattern of the organism at the given time, and direct external stimuli.

The original axis of highest activity, in general, maintains its dominance over the lower levels in the gradient and tends to become even more specialized in the transmission of stimuli in animals in which the hereditary potentiality for such specialization is present. Thus the region of first active growth in the arthropod egg becomes the ventral nerve chain and the similar region in vertebrates becomes the medullary plate and ultimately the brain and spinal cord.

In case a secondary center of activity becomes sufficiently isolated from the primary center, a second individual tends to be formed about it. Separate individuals may result as in the asexual reproduction of many lower vertebrates or a system with mechanical continuity and perhaps transportative coordination, between parts, but only slight integration in behavior may result as in plants, hydroids, tapeworms, etc. Finally through a secondary reattainment of dominance by the primary center, a segmental organism may be produced as is suggested for annelids, anthropods and vertebrates.

THE SCOPE OF THE BOOK

This, in a rough way, may bring out Professor Child's theory of development to which the greater part of this book is devoted. Considerable attention is devoted to the nature of stimulation and transmission, to evidences for the existence of metabolic gradients in particular organisms, and to applications of the theory to special problems such as the development of the pattern of nerve cells and of the nervous system as a whole. Suggestive analogies with phases in the organization of human societies are frequently presented.

RELATION TO VITALISM

The theory, as a mechanistic one, seems the very antithesis of such views as those set forth by Driesch with his quasi intellectual factor, the entelechy, as the guiding spirit of development, and by Bergsen with his elan vital. In a sense, however, there is a curious approach. Under Child's theory there is complete continuity from the reaction of the cell with its environment which constitutes the primary metabolic gradient, and from the later reactions by which the pattern of the developing embryo is laid down in accordance with the changing gradient pattern, to the intellectual processes by which the adult organism adjusts its relations to the outside world. Since awareness is certainly associated with the dominating nervous activities in the latter case, it seems necessary to grant the possibility of its presence in the former, unless we wish to assume that it is arbitrarily superimposed upon metabolic gradients at a certain level of complexity. Moreover as a state of consciousness in the higher case is certainly closer to reality than any impressions which it may make on other consciousnesses, the question at least seems open as to whether the entelechy may not be the reality of which the metabolic gradient, however much correlated with environmental factors, is merely the outward show.

However this may be, it does not, of course detract at all from the vastly greater significance to science of such a conception as that which Child presents.

RELATION OF GENETICS

From the standpoint of the geneticist it is to be regretted that the author has made no attempt to bring the facts of genetics into relation with his theory.

The geneticist, to some extent, is able to deduce the nature of details in cell organization from observed differences among adults at the very opposite end of the developmental series. He finds an enormous number of cases in which differences in adult characteristics are inherited in such a way as to make it necessary to believe that they depend on differences in real units of the cell organization. These units can be handed on for an indefinite number of generations, in association with the most varied collections of other units, without suffering change. If absent, they can not be reconstituted by the cell. They must divide as a rule with the most perfect equality at each cell division. They must, in short, be veritable organic individuals, though merely of molecular dimensions, living in the cell, and reproducing by fission at each cell division.

Geneticists have not only learned much about the nature of these entities in the cell, but find a great deal of evidence as to just where they live. They are transmitted in inheritance as if each were located in a definite place in one of a definite number of separate chains. Evidence of the most direct kind indicates that these chains, deduced from breeding experiments, are none other than the chromosomes actually visible in the cell nucleus.

Geneticists, moreover, have discovered the fact, rather embarrassing to an extreme preformation viewpoint, that there is no relation between the arrangement of these units in the cell, and the kind of characteristic of the adult in which their absence or modification results in visible change. In the fruit fly for example, factors which seem to affect only eye color are found to be scattered at random among the different chromosomes and the same is true of factors which seem to affect only eye shape, wing venation, body color or bristles. In some cases moreover, a single hereditary unit is responsible for differences in apparently unrelated parts of the body.

With all of this knowledge of the ultra-microscopic constitution of the cell, and of the one to one relations between cell units and differences in adult characteristics, the geneticist can as yet say little as to how the unit factors determine the course of development. His scheme lacks motion. Some such conception as that of Child is needed to show how one system gives rise to the other. Child's theory on the other hand must take account of the details of heredity if it is to get beyond the vagueness which leaves it rather obscure as to why one egg develops into a cabbage, another into a man with brown eyes and another into a man with blue eyes.

The location of unit factors in the chromosomes, indeed their very existence, is, however, dismissed by the author as an extreme and impossible preformist view. He apparently looks on the cell as an organization in a particular kind of matter, determined merely by a surface-interior gradient in relation to external conditions. This view overlooks the great body of cytological evidence which indicates that each of the chromosomes and, indeed, each of the granules visible along the chromosomes in the thin thread stage, is a self perpetuating individual, as well as the genetic evidence for the individuality of the unit factors, referred to above.

COMPATIBILITY OF SIMPLE MECHANISMS OF HEREDITY, AND DEVELOPMENT WITH A COMPLEX CELL ORGANIZATION

To the reviewer, however, the genetical and cytological conception of the cell, as an association of independent organisms, living in a relatively large,

less specialized mass of protoplasm and controlling the behavior of the whole in response of course to external stimuli, is not at all incompatible with a simple mechanism of heredity and a simple physiological conception of development such as that offered by Child. It is, of course, impossible to assume that the genetic basis of the differences among the millions of species of animals and plants, and the millions of individuals within each species can be very simple. It must be remembered, however, that a given cell complex has not developed out of nothing in the course of a few weeks, as the individual seems to do. It is the result of millions of years of uninterrupted slow change. The problem of heredity is merely to explain the lack of interruption in this history, i.e. the persistence of the complicated cell organization through cell division and fertilization. The mechanisms by which all of the essential entities within the cell are caused to reproduce by simultaneous fission (mitosis) and under other conditions to conjugate in pairs (synapsis) need not be very complex.

As to individual development, there seems to be no incompatibility with Child's explanation of its course as the behavior pattern of a particular kind of cell in relation to the metabolic gradient determined ultimately by the environment. The hypothesis that the activities of the different unit factors vary at different rates according to the position of the cell in the gradient pattern of the developing organism and to the specialization which the cell has already undergone as a result of its past history, thus determining the details of the "organismic pattern," in reaction of course with the environment, seems a necessary supplement to Child's highly suggestive hypothesis.

Fewer Births in United States

Births in the registration area (comprising about 58% of the total population) of the United States in 1919, recently compiled by the Census Bureau, show a slight decrease for the first time. This is presumably a consequence of the war, and the absence from home of a considerable part of the male population.

In the birth registration area exclusive of Rhode Island, which failed to send in transcripts of birth certificates, 1,365,585 infants were born alive in 1919. The total number of deaths in the same area was 791,732, the births exceeding the deaths by 573,853, or 72.5 per cent.

The number of births for the year 1919 compared with 1918 shows a decrease of 7 per cent in the registration area. Each state shows a decrease, the per cent ranging from less than one in Maryland to ten in Utah and Wisconsin. This is in marked contrast to previous years as the number of births had increased from year to year.

The infant mortality rate (number of deaths of infants under 1 year of age per 1,000 born alive) is 87 in 1919 and is the lowest infant mortality rate on record in the birth registration area. Among the states these rates range from 63 in Oregon and Washington to 113 in South Carolina.

The Social Hygiene Movement

SANITY IN SEX, by William J. Fielding. Pp. 333. New York, Dodd, Mead and Co., 1920.

Mr. Fielding presents a survey of the sex-education movement of recent years, particularly that which was an outgrowth of attempts to protect the health and morale of the armed forces during the war. He gives one of the best popular accounts available of the social hygiene work of this period. His chapters dealing with birth-control and psycho-analysis are less adequate, and none too well founded, biologically.—P. P.

HERITABLE CHARACTERS OF MAIZE

VII. SHRUNKEN ENDOSPERM[1]

C. B. HUTCHISON
New York State College of Agriculture, Cornell University, Ithaca, N. Y.

IN 1914 Professor R. A. Emerson received from Dr. M. R. Gilmore of the Nebraska Historical Society several small packages of maize seeds which the latter had collected the previous year from gardens of the Ponka Indians on the Niobrara reservation in Nebraska. Among these packages was one containing starchy and sugary, white, red, and purple, and self-colored and speckled kernels, all of which had been taken from a single ear. These seeds were planted at the Nebraska Experiment Station by Dr. Emerson and a number of the resulting plants self-pollinated. On one such self-pollinated ear in this pedigree there appeared among the starchy kernels certain ones with an unusual type of indentation. The kernels of flour corn ordinarily are not indented at all but are smooth and rounded in shape like flint corn. The starchy kernels on this ear were floury in texture and most of them smooth and rounded. Some, however, were deeply indented at the top with a smooth crease or, in the case of broad and thick kernels, with a deep dimple. Others were indented not at the top but on the sides, as if in drying the endosperm had shrunken and the sides of the kernel had fallen in. Still others were indented at both the top and sides which gave them a shrunken and pinched appearance. When these unusually shaped seeds were planted and the resulting plants selfed, they were found to breed true for this character and subsequent tests have shown it to be inherited as a simple recessive to the normal or full endosperm. It has been called "shrunken" and is designated by the genetic symbol *sh*, the dominant allelomorph of which is *Sh*.

In 1918 shrunken was crossed with a number of other types of maize to determine its relation with other known genetic factors. Subsequently, thru the kindness of Dr. Emerson, all of this material came into possession of the writer.

DESCRIPTION OF SHRUNKEN ENDOSPERM

An adequate conception of the nature and general appearance of shrunken kernels may best be had from examination of the accompanying illustrations. In Figure 20 two selfed ears from homozygous shrunken plants are shown and in Figures 21 and 22 ears containing both shrunken and non-shrunken kernels in approximately equal numbers. The latter ears are the result of pollinating plants heterozygous for the factor for shrunken with pollen from homozygous shrunken plants. Figures 23 and 24 show different views of shrunken and non-shrunken kernels taken from the same ear.

It will be noted from Figures 21 and 22 that where the rows are straight and the kernels fairly uniform, especially in the middle portion of the ear, shrunken kernels are usually more flat, somewhat broader, and frequently shallower than non-shrunken ones. In such kernels the top is usually folded in to form a deep and smooth crease altho at times the indentation is from the sides of the kernel giving them a pinched appearance and leaving considerable space between the kernels at the top. On the butt or tip of the ear where the kernels normally are irregular in shape, or where adjoining kernels fail to develop, shrunken kernels are characterized by a deep, broad and rounded dimple.

The shrunken indentation is sometimes not unlike the creased or rounded dimple found in ears of a flinty type of dent corn—particularly on the butt

[1] Paper No. 87, Department of Plant Breeding, Cornell University, Ithaca, New York. Photographs by W. I. Fisher.

SHRUNKEN KERNEL MAIZE EARS BRED FROM PONKA INDIAN CORN

Among some maize seeds obtained from the Ponka Indians of Nebraska in 1914 were some that were deeply indented at the top and some indented on the sides, as though the endosperm had shrunken causing the sides to fall in. When these seeds were planted they were found to breed true, and subsequent tests have shown this condition to be inherited. (Fig. 20.)

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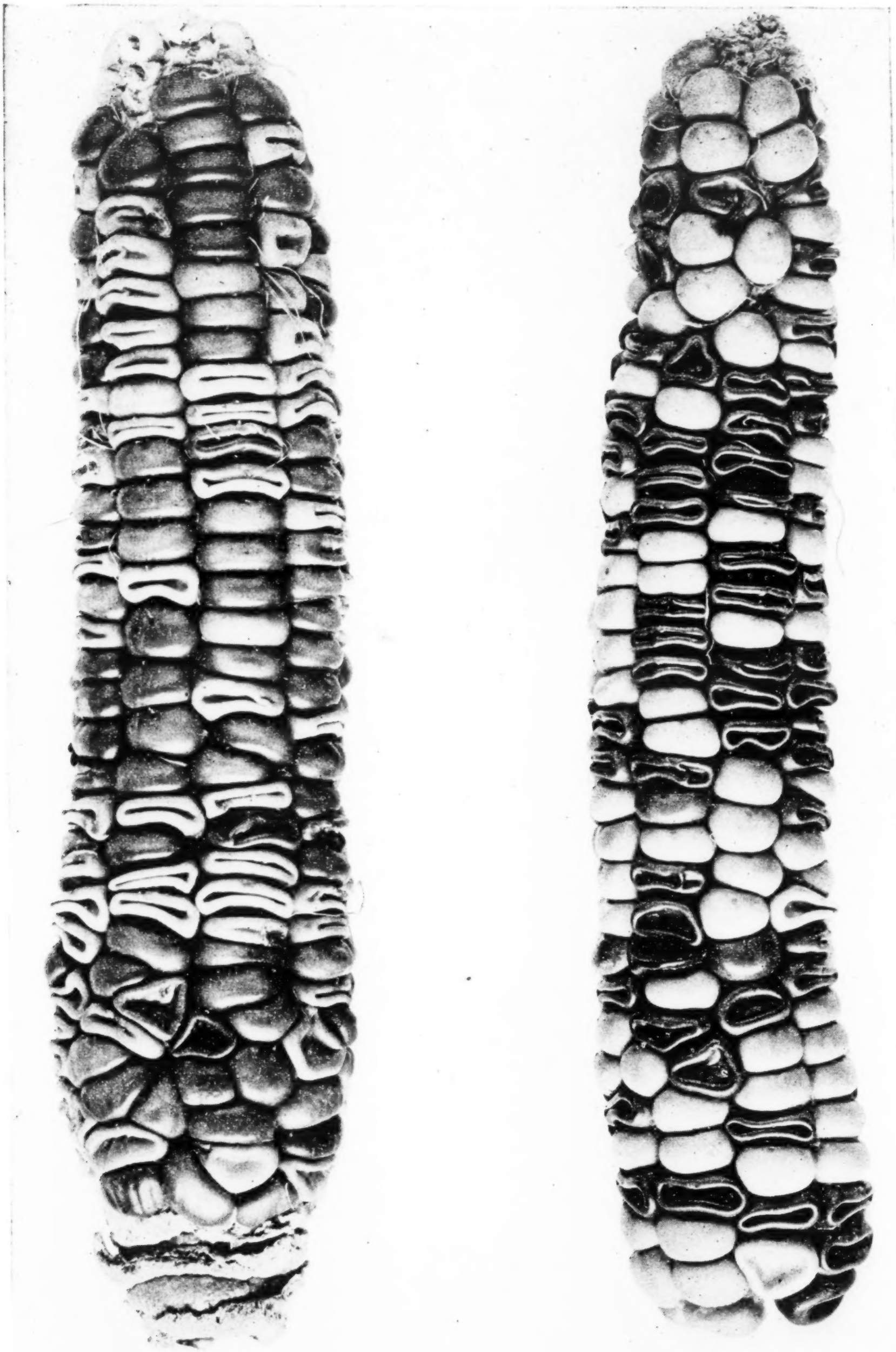
EARS WITH BOTH SHRUNKEN AND NON-SHRUNKEN KERNELS

One of the parents of this hybrid had colored seeds with shrunken endosperm, and the other had white seeds which were not shrunken. These hybrid ears show that the parental combinations tend to reappear, that is most of the colored seeds are shrunken while the colorless ones are not. (Fig. 21.)



SHOWING SHRUNKEN ENDOSPERM IN BOTH WHITE AND COLORED SEEDS

The kernels on these ears show linkage of the shrunken endosperm character with two different aleurone characters. (Aleurone is the thin external layer of the kernel containing the color character.) The ear at the left is the result of crossing a hybrid plant with one that was pure for colorless aleurone and non-shrunken endosperm. In this instance one of the parents of the hybrid was white and shrunken and the other was colored and not shrunken. Again the parental combinations reappear, most of the white seeds being shrunken and the colored ones not. In the ear at the right the parent of the hybrid with non-shrunken endosperm also had white aleurone. Note that very few of the white seeds are shrunken, showing that this aleurone factor also is linked with the new character, shrunken endosperm. (Fig. 22.)

and tip kernels. Usually, however, the dimple or crease is much more pronounced than in ordinary dent corn. The shrinking from the sides of the kernel presents a condition which the writer has never observed in dent corn, the indentation of which is usually rough and always at the top. The most striking difference in the two types of indentation aside from one of degree is the fact that in shrunken kernels a cavity is usually found within the upper part of the endosperm as if the cells in this region had not been filled with starch as the kernel matured (See Figure 24.) Previous to the hard dough stage shrunken kernels are smooth and rounded in outline. As they begin to dry the top or sides sink in to such an extent at times that the cavity is closed altho its outline may be distinctly seen. In other cases, particularly where there is a fairly thick layer of corneous starch at the top of the kernel the latter may be almost smooth in outline. In such kernels the cavity beneath the shell of corneous starch is very pronounced. On the other hand, in dent corn the endosperm is filled, the indentation being due to a greater shrinking of the soft starch at the top of the kernel than of the corneous starch on the sides.

By reason of this fact, little difficulty has been found in distinguishing shrunken from non-shrunken kernels with starchy endosperm. It is difficult, however, always to classify shrunken and non-shrunken kernels in sweet corn, particularly on ears of the Country Gentlemen type where the kernels are long, narrow and pointed and very irregular in shape. Such separations are much more readily made on eight or ten rowed ears of sweet corn where the kernels are broad and rounded and fairly regular in outline.

In examining shrunken and non-shrunken kernels one is apt to gain the impression that the former are lighter in weight than the latter since they are apparently not fully developed. This, however, is not the case. Data obtained by weighing the shrunken and non-shrunken kernels on the ears from six F_1 plants that had been backcrossed to shrunken show that while the non-shrunken kernels are slightly heavier the difference is not statistically significant. These data are given in the following table:

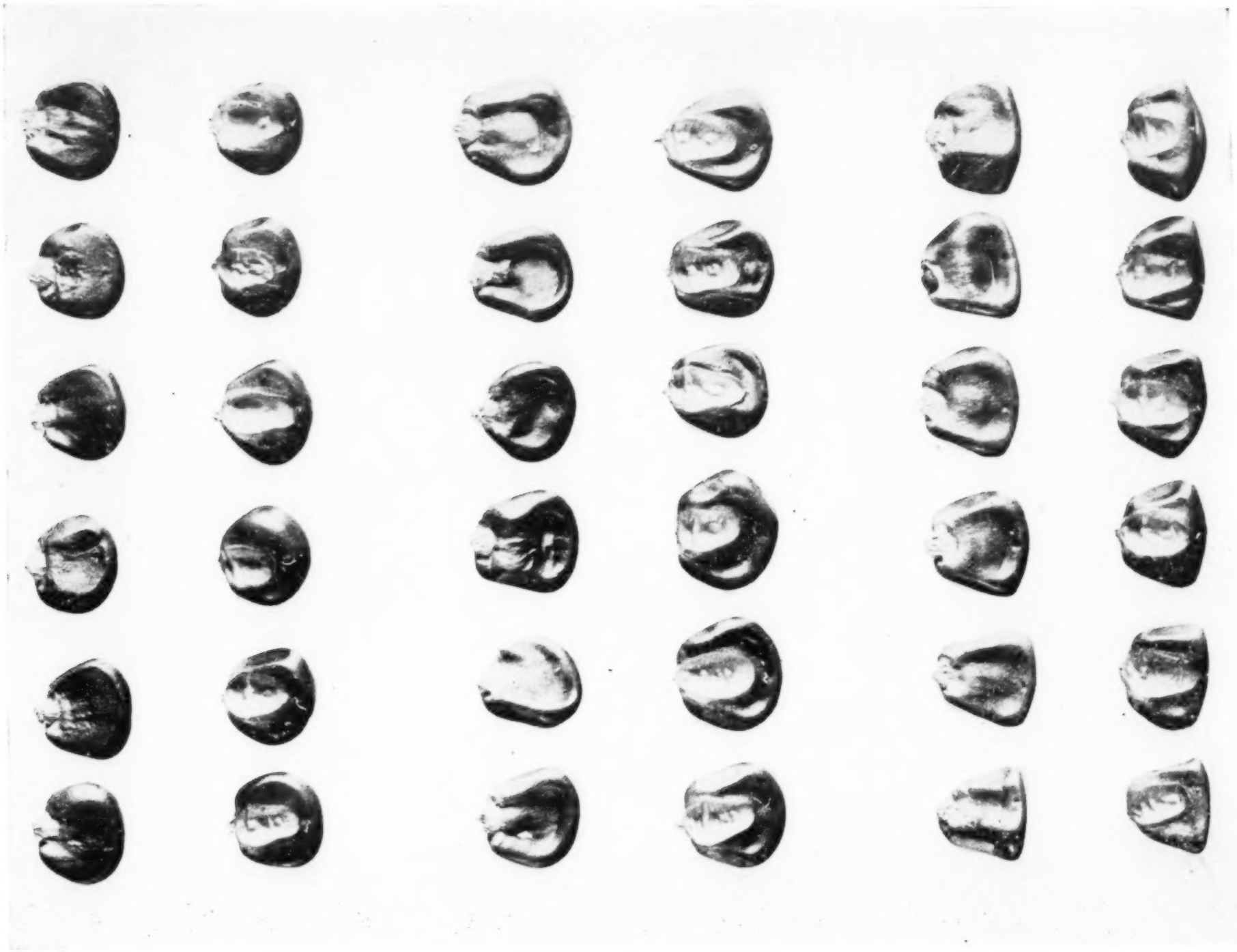
	Number of kernels weighed	*Average weight of kernels*
Non-shrunken	914	272 ± 8.42 mg.
Shrunken	874	259 ± 10.89 mg.
Difference		13 ± 13.76 mg.

INHERITANCE OF SHRUNKEN ENDOSPERM

As stated above the character shrunken endosperm is inherited as a simple recessive to the normal or non-shrunken. Numerous crosses have been made between shrunken and non-shrunken plants and the F_1 seeds produced have been normal in all cases. A number of such hybrid kernels have been planted and the resulting plants selfed for F_2 progenies. Two such progenies consisted of 705 non-shrunken and 239 shrunken kernels. This is a deviation of only 3 ± 8.97 seeds from the 3: 1 relation expected when the parents differ in a single pair of factors. A number of F_1 plants also were backcrossed with the recessive shrunken in connection with some linkage studies to be described later. A total of 20,556 kernels resulting from such backcrosses have been examined, of which 10,295 were shrunken and 10,261 non-shrunken. This is a deviation of only 17 ± 48.3 seeds from the 1 : 1 ratio expected. Evidently shrunken endosperm is differentiated from the normal by the single factor pair *Sh sh*.

LINKAGE RELATIONS OF *Sh sh* AND *Wx wx*, AND *Sh sh* AND THE ALEURONE FACTORS *C c* AND *I i*

The fact that waxy endosperm and aleurone color in maize are linked was first established by Collins and Kempton (1911). Bregger (1918) was able to show that the particular aleurone color factor concerned is the *C c* pair. Among the crosses made by Dr. Emerson in 1918 with shrunken one involved



LATERAL VIEWS OF SHRUNKEN AND NON-SHRUNKEN KERNELS FROM A SINGLE EAR

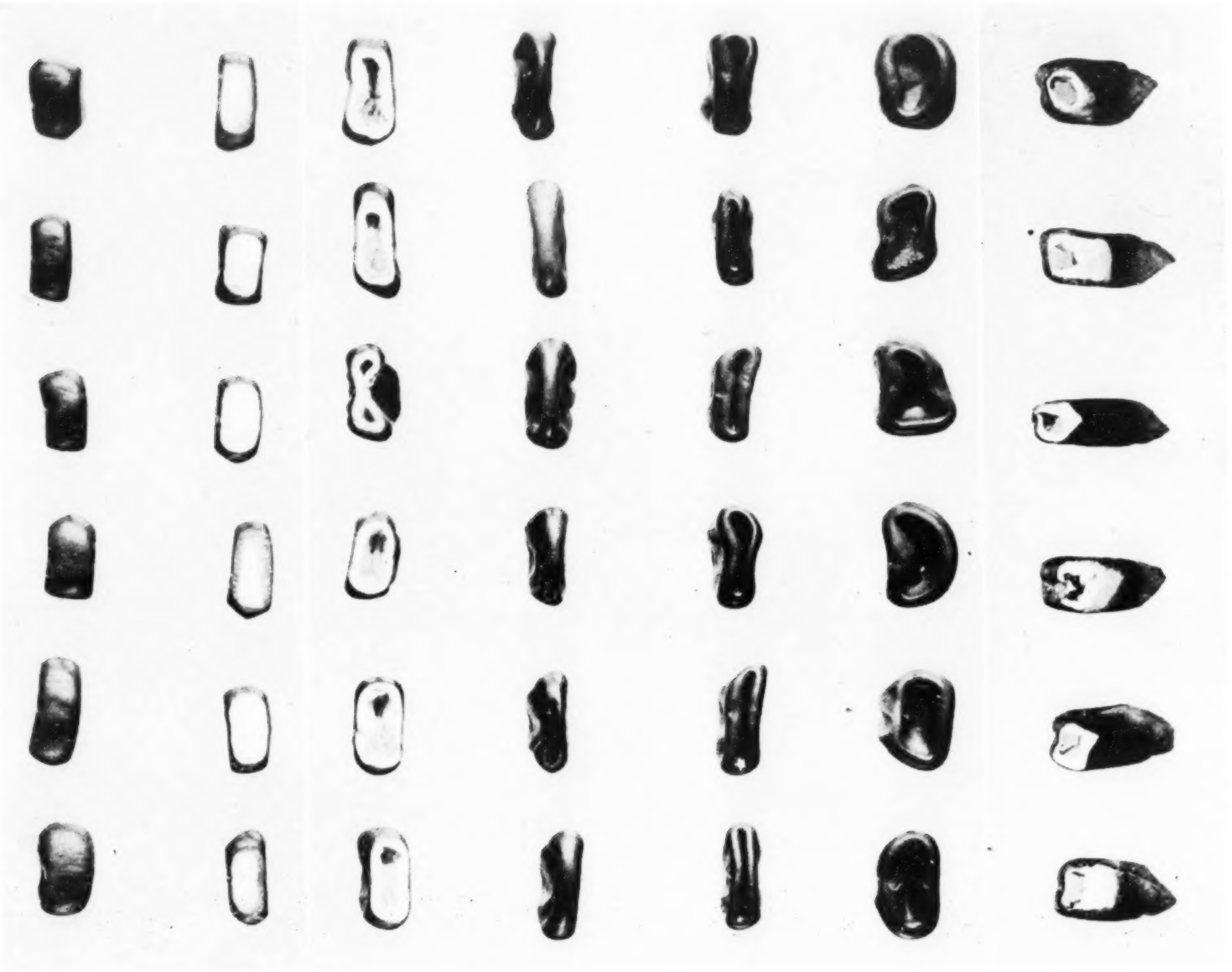
The two rows at the left are non-shrunken kernels; in the middle two rows the indentation is from the sides of the kernels, and in the two rows at the right the indentation has taken the form of a deep crease. The latter character is shown better in the kernels in the centre of Fig. 24. (Fig. 23.)

the *C c* and *Sh sh* factor pairs. A homozygous red aleurone shrunken plant of the genetic constitution *C C sh sh* was crossed with a colorless aleurone non-shrunken plant of the constitution *c c Sh Sh*. An F_1 plant of this cross, grown in the greenhouse during the winter of 1918–19, was selfed giving a small F_2 progeny. On this ear shrunken and non-shrunken kernels were found as well as colored and colorless but all of the shrunken kernels were also colored. This clearly indicated that the *Sh sh* and *C c* factor pairs are linked. To definitely establish the fact the writer in 1919 made a number of backcrosses between F_1 plants and the double recessive. Twenty-eight such backcrossed ears gave progenies totaling 8,326 kernels distributed as follows:

Colored non-shrunken	Colored shrunken	Colorless non-shrunken	Colorless shrunken
136	3,992	4,049	148

The parental combinations of the characters concerned in this cross are in great excess, there being 8,041 kernels of these combinations and only 284 of the other two. This is very far from equality which is expected with independent inheritance. It is evident that the factor pair *Sh sh* belongs to the same linkage group as *C c* and *Wx wx*, with a crossover percentage in this case of approximately 3.4 for *Sh sh* and *C c*. In Figure 21 two such backcrossed ears are illustrated. It will be noted that most of the colored kernels are shrunken and most of the colorless ones are smooth. A few kernels of the opposite combinations, however, are to be found on each of these ears.

The ear on the left in Figure 22 illustrates the coupling series of these two factor pairs. In this case the parental combinations were *C Sh* and *c sh*. This ear is the result of pollinating an F_1



CROWN AND EDGE VIEWS OF NORMAL AND ABNORMAL KERNELS

The first two rows at the left show kernels in which the endosperm is completely developed. Those in the third row are cut in cross-section to show the cavities which are often found in the upper part of shrunken kernels. The 4th, 5th and 6th rows show the variation in the size and shape of shrunken kernels. In the last row at the right the kernels are cut to expose the cavities in the upper part of the endosperm. (Fig. 24.)

plant of the genetic constitution $\frac{C\ Sh}{c\ sh}$ by the double recessive $\frac{c\ sh}{c\ sh}$. Again it will be noted that while most of the colored kernels are smooth and most of the colorless ones shrunken a few kernels show the opposite combinations of these characters.

To determine the linkage relation of shrunken and waxy a non-shrunken waxy plant of the genetic constitution *Sh Sh wx wx* was crossed with a shrunken starchy plant of the constitution *sh sh Wx Wx*. Several F_1 plants of this cross were backcrossed to double recessive shrunken waxy plants. Twelve ears were obtained from these pollinations containing a total of 2,105 kernels which were distributed among the four possible classes as follows:

Non-shrunken starchy	Non-shrunken waxy	Shrunken starchy	Shrunken waxy
229	813	833	230

Here the parental combinations of the two factor pairs concerned total 1,646 and the new combinations 459. The crossover percentage for *Sh sh* and *Wx wx* in these particular crosses is 21.8.

On the basis of these data the probable order of the three genes in this linkage group is

C	Sh	Wx
c	sh	wx
O	3.4	25.2

It must be remembered, however, that the percentage of crossing-over is variable and that the order of the genes can definitely be determined only in backcrosses where all three pairs of factors are involved at once. Material

is now available for making this three point test.

Shrunken has also been crossed with another aleurone factor *I i*, the existence of which was first established by East and Hayes (1911). The interaction of the recessive allelomorph *i* of this factor pair with the dominant allelomorphs of three other factor pairs *A a*, *C c* and *R r* is necessary for the development of aleurone color (Emerson, 1918). When the dominant allelomorph *I* is present no color develops. A homozygous red aleurone shrunken plant with the constitution *i i sh sh* was crossed with a homozygous non-shrunken plant which was also homozygous for *I* and, therefore, had colorless aleurone. Its genetic constitution for the factors in question was *I I Sh Sh*. The immediate kernels produced were colorless and non-shrunken. Several F_1 plants produced by these kernels were backcrossed to the double recessive. Twenty-eight backcrossed ears were obtained with a total of 7,294 kernels. All four combinations of the characters in question appeared among these kernels, the numbers in each class being as follows:

Colored non-shrunken	Colored shrunken	Colorless non-shrunken	Colorless shrunken
134	3,509	3,525	126

The parental combinations here total 7,034 while the other two total only 260. It is evident, therefore, that the factor pair *I i* also belongs with the *C c Sh sh Wx wx* linkage group. The crossover percentage for *I i* and *Sh sh* in this case is 3.6. One of these backcrossed ears is shown on the right in Figure 22.

The very close approximation of the *Sh sh*—*C c* linkage relation by that of *Sh sh*—*I i* suggests three interesting possibilities. *C c* and *I i* are (1) very closely linked, (2) they are on opposite sides of *Sh sh* and approximately equally distant, or (3) they are allelomorphic. It is impossible at present to determine which of these possibilities is correct but investigations are now in progress which are expected to throw some light upon the problem.

Literature Cited

Bregger, T. Linkage in maize: the *C* aleurone factor and waxy endosperm. Amer. Nat. 52: 57–61. 1918.

Collins, G. N. and Kempton, J. H. Inheritance of waxy endosperm in hybrids of Chinese maize. International Conference of Genetics, Paris, 4: 547-556. 1911.

East, E. M. and Hayes, H. K. Inheritance in maize. Connecticut Agr. Exp. Sta. Bul. 167: 1–142. 1911.

Emerson, R. A. A fifth pair of factors, *A a*, for aleurone color in maize, and its relation to the *C c* and *R r* pairs. Cornell Univ. Agr. Exp. Sta. Mem. 16: 227–289. 1918.

Fellowship in Crop Breeding

There will be a fellowship in the study of crop improvement at the Michigan Experiment Station, East Lansing, Michigan, to be filled on or before September 1st, 1921. It is a half-time fellowship, open to graduates of our Universities with farm experience or graduates of Agricultural Colleges, who have had a good course in genetics, the more genetics the better.

The holder of the fellowship is expected to complete a master's degree in two years, majoring in plant breeding and taking his minor in some other department. Half of his time will be devoted to actual crop improvement work, connected with the Department of Farm Crops.

The breeding work during the coming year will include work on corn, oats, rye, wheat, beans, alfalfa, clover, fiber, flax, hemp, potatoes, sugar beets, timothy, and winter vetch.

The candidate would need to furnish a copy of his grades from the Registrar's records, and give references to those who know of his abilities. The fellowship offers $800 for half time during each of two years. Interested persons should communicate with the Department of Farm Crops, Michigan Agricultural College, East Lansing, Michigan.

POLYDACTYLISM IN CATTLE[1]

ELMER ROBERTS
Agricultural Experiment Station, Urbana, Illinois

THE inheritance of extra digits or polydactylism has been studied in poultry, guinea-pigs and man. Its occurrence in cattle has been known for a long time and many cases have been recorded. Through the kindness of Dr. C. B. Olney who called my attention to its presence in a herd of dairy cattle owned by Mr. Paul Peglow, Prairie View, Illinois, an opportunity was afforded to note the inheritance of this character in cattle.

A normal bull mated to a polydactylous cow having three toes on each foot produced a female showing the same condition. Information concerning other offspring was not available. This latter female mated to a normal, unrelated bull has produced three male calves all of which were polydactylous. Two of these were like the mother having three toes on each foot, while the third had three toes on each front foot, four on one hind foot and five on the other. In the hind legs of this third calf there was said to be a duplication of the normal number of bones between the hock and the hoof, that is of the metatarsals.

Figure 28 illustrates graphically the inheritance of this character. Figures 26, 29 and 30 show the expression of the polydactylous condition in the dam of the three calves. Figure 25 is of the normal foot in cattle. It should be noted that the extra toes on front feet are much

COW'S NORMAL FOOT

POLYDACTYLOUS FOOT

Polydactylism is the possession, by man or animals, of more than the normal number of digits. The case described here is another proof of the inheritance of this abnormality. The polydactylous foot shown at the right above is a close view of the right hind foot of the cow pictured on the opposite page. (Figs. 25 and 26.)

[1] Paper No. 15 from the Laboratory of Genetics, Illinois Agricultural Experiment Station.

A GRADE HOLSTEIN COW WHICH HAS THREE TOES ON EACH FOOT

The mating of a normal bull to a polydactylous cow having three toes on each foot produced a female possessing the same condition. The latter female mated to a normal, unrelated bull has produced three male calves all of which were polydactylous. The inheritance of the abnormality in this case is outlined in the diagram below. (Fig. 27.)

smaller than those on the hind feet. In each case the third toe is on the inside. This would mean that the extra toe is probably a development of the I or II digit, and probably the II.

In poultry, guinea-pigs and man, the expression is variable. Sometimes it is dominant and at other times normal individuals produce polydactylous offspring. Also many other factors seem to influence its expression. In this case in cattle it is obviously dominant.

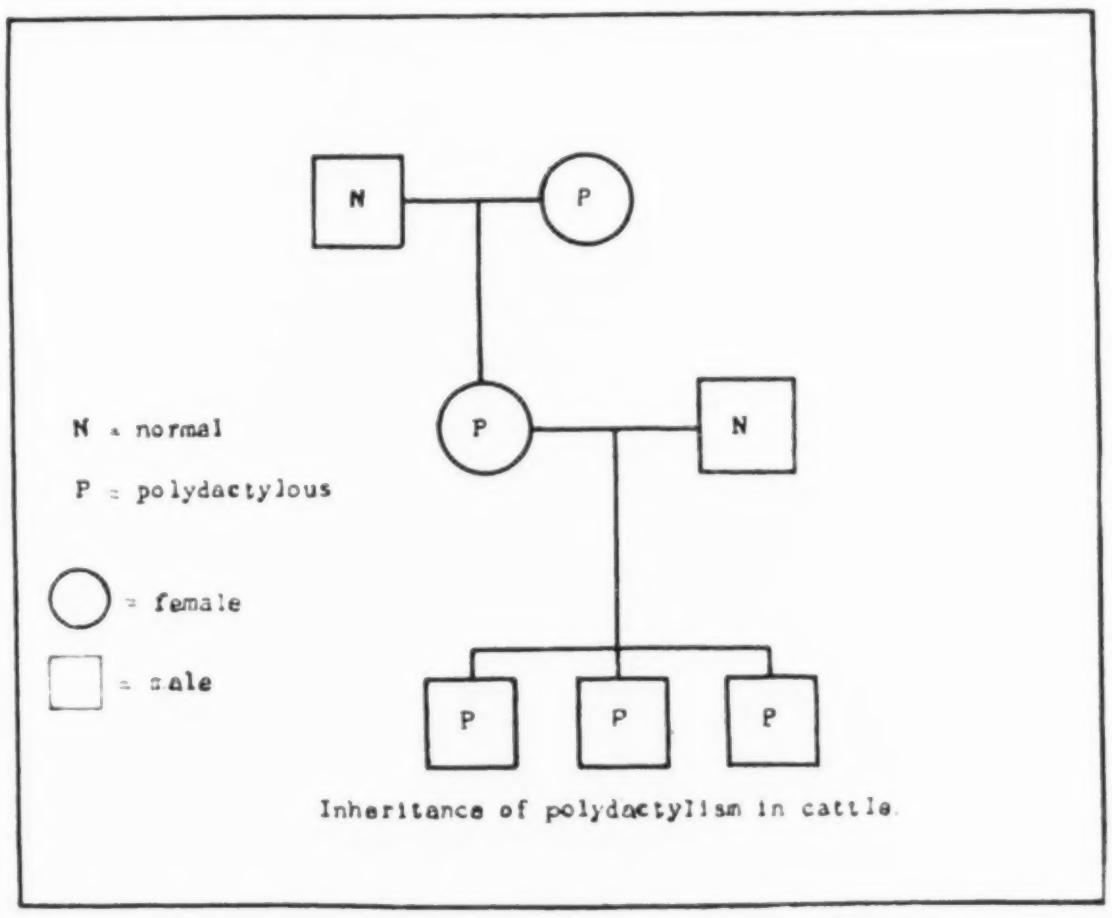


Fig. 28

HIND FEET OF THE POLYDACTYLOUS COW SHOWN IN FIG. 27 (FIG. 29)

FRONT FEET OF THE POLYDACTYLOUS COW SHOWN IN FIG. 27

Note the small size and asymmetrical position of the extra toes. In this case the polydactyly appears to be due to the recurrence of a latent ancestral digit and is thus comparable to polydactyly in guinea pigs. In human and feline polydactyly there is a symmetrical reduplication of one or more of the digits apparently due to an irregularity in development which is without atavistic significance. (Fig. 30.)

A TOOTHLESS TYPE OF MAN[1]

The "Bhudas" of India—A Case of Sex-linked Inheritance

K. I. THADANI, B. Ag.
Agricultural Department, Bombay, India
(Graduate Student in the A. & M. College of Texas, College Station, Texas)

THERE occurs in the Hindu Amil community of Hyderabad Sind, a town in India, a type of men who have no teeth. These men are further characterized by a bald head and an extreme sensitiveness to heat. They are known as "Bhudas," which literally means "toothless." The following facts are known about them:

(1) When such a man (a Bhuda) marries a normal girl having both parents free from these defects, all the children, both males and females, are apparently normal—that is to say, apparently free from the defect.

(2) When the F_1 males marry normal females having both parents normal, their children, both males and females, are apparently normal.

(3) When the F_1 females marry normal males, their female children are apparently normal, while the male children are "Bhudas."

(4) No case is known in which a toothless man has married the daughter of a "Bhuda."

(5) No females have been found showing the anodont condition.

BIOLOGICAL EXPLANATION OF THE PHENOMENON

This is, apparently, a case of sex-linked inheritance in man. The inheritance of this toothless condition, as well as the associated defects of sensitivity and hairlessness, is a case in point, and the causative character seems to be carried by the sex chromosomes. The factors involved are: B for the normal condition, and its recessive allelomorph "b" for the toothless condition.

(a) When a female of the genetic constitution (BX) (BX) is mated to a male (bX) Y, we get:

	Genotypes	*Phenotypes*
F_1	(BX) (bX)	Normal females.
	(BX) Y	Normal males.

That is to say all the children are normal in appearance. This explains fact No. 1, stated above.

(b) Fact No. 2 is self-explanatory when we consider the genetic constitution of the F_1 male.

(c) Fact No. 3 carries us to the F_2 generation. When an F_1 female (BX) (bX) marries a normal male (BX) Y, who has the same genetic constitution as her F_1 brother, then we shall get:

	Genotypes	*Phenotypes*
F_2	(BX) (BX)	Normal female.
	(BX) (bX)	Normal female.
	(BX) Y	Normal male.
	(bX) Y	Toothless male.

The following points are worth noting:

(1) We expect all females to appear normal; this is what acutally happens in practice. So the theoretical expectations coincide with the practical results.

(2) Of the males we expect some toothless, some normal, strictly speaking one to one. Now let us see what actually occurs in practice. The general belief is that all males are toothless, but this is a matter for further investigation. At the same time, the absence of normal males in the F_2 generation in actual practice can be explained by taking into consideration the fact that only one individual is produced at a time, therefore the chances of one of the phenotypes not appearing at all, or another appearing repeatedly, are as great as the chances of all the phenotypes (comprising 4 genotypes in the present case) being represented in a single generation. In order that all of the phenotypes may appear, we must have a sufficient number of individuals under observa-

[1] A preliminary report.

tion, a condition not under control. But the fact remains that there is a possibility of any of the phenotypes not already observed appearing sooner or later. So that whenever such appear, they are easily accounted for. Further, we must note that in the practical observations that are known to us, there is nothing that can not be accounted for; there is nothing that conflicts with our theoretical expectations.

(3) The Mendelian ratio of 3 : 1 in the F_2 generation is apparent, but we have no data as to how far it is attained in actual practice. However, we must remember that this ratio should be looked for only in those organisms in which a reasonably large number of individuals are born in a generation.

(d) Facts Nos. 4 and 5 are interrelated, one being the cause, and the other its effect. A toothless female (bX) (bX) can only result when a heterozygous female (BX) (bX) is mated to a toothless male (bX) Y, a condition not yet attained in practice.

CONCLUSION

(1) The toothless man seems to be an example of regressive mutation.

(2) The phenomenon of heredity in the toothless man is strictly a case of sex-linked inheritance, as all the existing facts are in conformity with our theoretical expectations based on Mendelian laws of Segregation and Dominance.

PRACTICAL SIGNIFICANCE

Since heredity in the toothless man obeys the laws of Segregation and Dominance, we can predict some of the important facts summarized below.

(1) A normal male, even if he is a son of a toothless man, has no contamination of this defect in his germplasm; no fear need be entertained about his carrying the defect in his germ without he himself showing it.

(2) The daughter of a toothless man, altho she does not show the defect in her body, carries the contamination hidden in her germplasm and will produce, on union with a normal male, some toothless children, and these will be males, with the complete exclusion of the toothless female children. But if she marries a toothless male there is a possibility of her producing both toothless and normal females, and also both toothless and normal males.

(3) Should, at any time, a toothless female appear, and should she marry a toothless man, then all their children, whether males or females, will be toothless without exception.

INFORMATION WANTED

The writer of this article would be glad to hear from anyone who can report if, at any time, any of the toothless men ever had (or has) a brother (from the same mother) who was normal, that is to say, was *not* a "Bhuda"; if any of his sisters (from the same mother) had all toothless sons while another had some normal sons.

The Diseases of Infancy

LEITFADEN DER KINDERHEILKUNDE für Studierende und Aertze; erster Teil, SÄUGLINGSKRANKHEITEN; 4te, verbesserte Auflage. Von Dr. Walter Birk, professor d. Kinderheilkunde a.d. Universität Tübingen. Pp. 269, broschiert M. 12.50, gebunden M.15.50. A. Marcus and E. Webers' Verlag, Bonn, 1920.

Dr. Birk lays out his subject methodically and sticks to it in a practical way that gives little opportunity for excursions into the field of genetics; although much might be written on the part that heredity plays in the diseases of the first year of life. His brief remarks on the frequency with which twins show marked difference as regards constitutional disease, make one desire further elaboration on this point.—P. P.

INBREEDING AND CROSSBREEDING

The Effect of Inbreeding and Crossbreeding in a Wild Plant of the Sunflower Family[1]

J. L. COLLINS
University of California

EVEN in very remote times the mating of closely related individuals in both the human race and in animals was considered to give rise either sooner or later to harmful or even disastrous results. Although such ideas contained much that was myth and superstition they were certainly founded on facts of such a nature that they could not be overlooked. Without this nucleus of fact the idea of evil resulting from inbreeding could not have persisted as it has through centuries.

It is only in the more recent of modern times that a logical explanation of the causes of such results has been made. A consistent explanation was possible only after a more thorough understanding of some hereditary phenomena in general had been worked out.

INBREEDING AND HEREDITY

In the cells of which a plant or an animal is composed there are a definite number of small particles of protoplasm called chromosomes. These chromosomes are supposed to carry the determiners called genes of factors for the characters which are hereditary. If the gene for a particular character is not present in the chromosome, that character will not be produced in the mature individual. Much of our knowledge relating to the causes of inbreeding and crossbreeding effects have come from experiments on inheritance in maize.

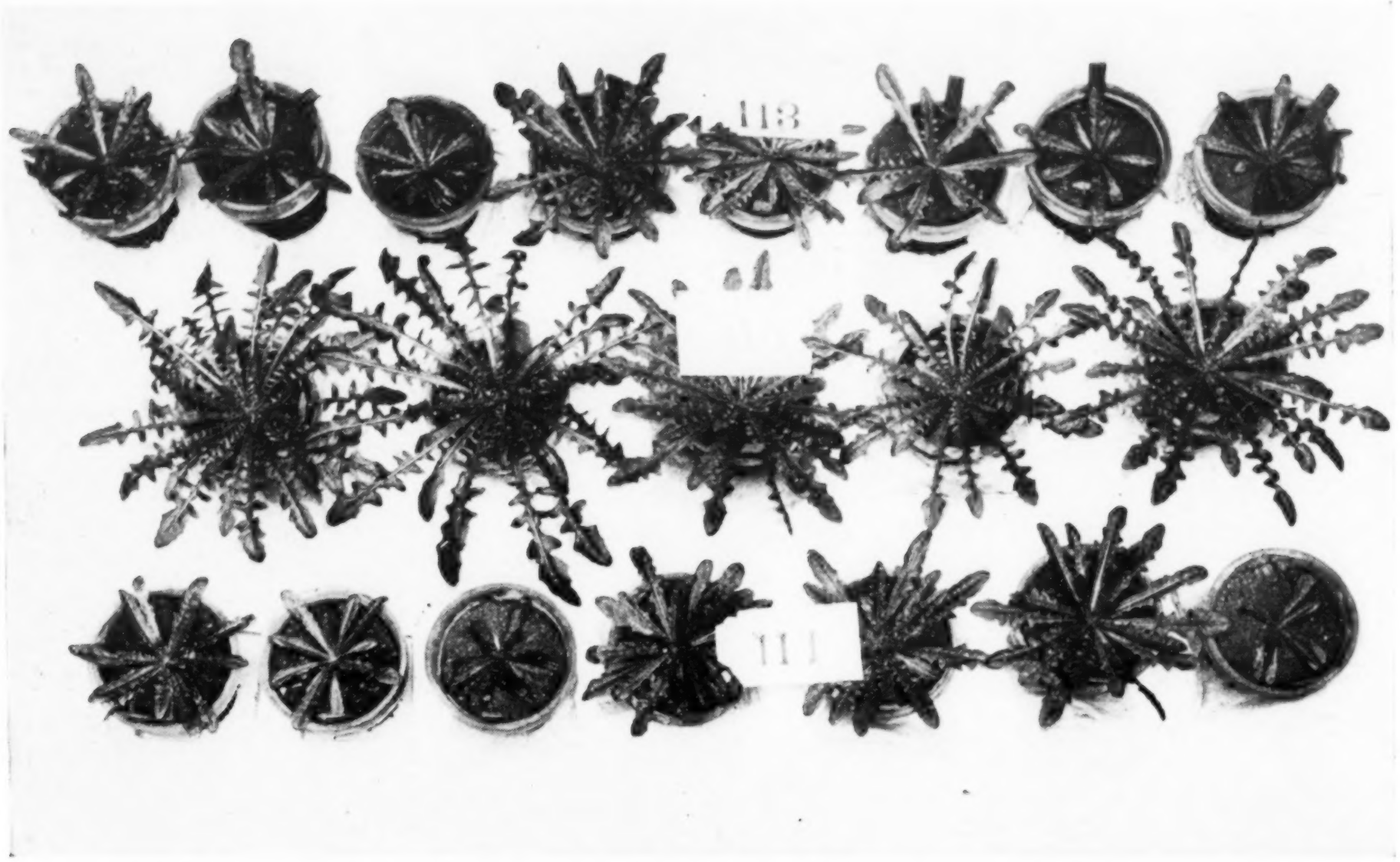
It has been shown that inbreeding itself produces no evil results, but that the characters which appear do produce an evil result because the hereditary gene or factor by which the character is conditioned is already present in the germplasm. If no such genes are present in the germinal material then no amount of inbreeding can produce them. In fact, inbreeding is now considered as a method of testing the hereditary material to determine if it carries the genes for any hidden or recessive characters. The fact then that inbreeding produces abnormal forms and a reduction of vigor in some species and not in others is due to the presence or absence of the genes in the germplasm. For example, no such results attend inbreeding in such self-fertilized crops as barley or beans because in them self-fertilization is the normal method of reproduction and these plants are homozygous for all their genes, all the abnormal and weak plants having long ago segregated out of the race and perished in the struggle against their more hardy sister plants, without leaving any progeny to perpetuate their kind.

CROSSED AND SELF-FERTILIZED PLANTS

Maize, on the other hand is a naturally cross-fertilized plant and heterozygosity is the general condition of the germinal material instead of homozygosity as in the case of the self-fertilized species. In this heterozygous condition the genes for these recessive harmful or abnormal characters may be carried along in the chromosome under the protection of the hardy, useful, dominant characters and manifest their presence only in the absence of the latter. Inbreeding in a naturally cross-fertilized species furnishes conditions favorable for the meeting of these recessive genes in the zygotes and hence their appearance in some of the individuals.

The increase in size and vigor observed in the progeny when two inbred strains or an inbred and unrelated non-inbred strains are crossed is due to the establishment of a heterozygous germplasm containing more dominant genes influencing size and vigor than

[1] By invitation.



MORE VIGOROUS HYBRIDS WITH LESS VIGOROUS INBRED WILD PLANTS

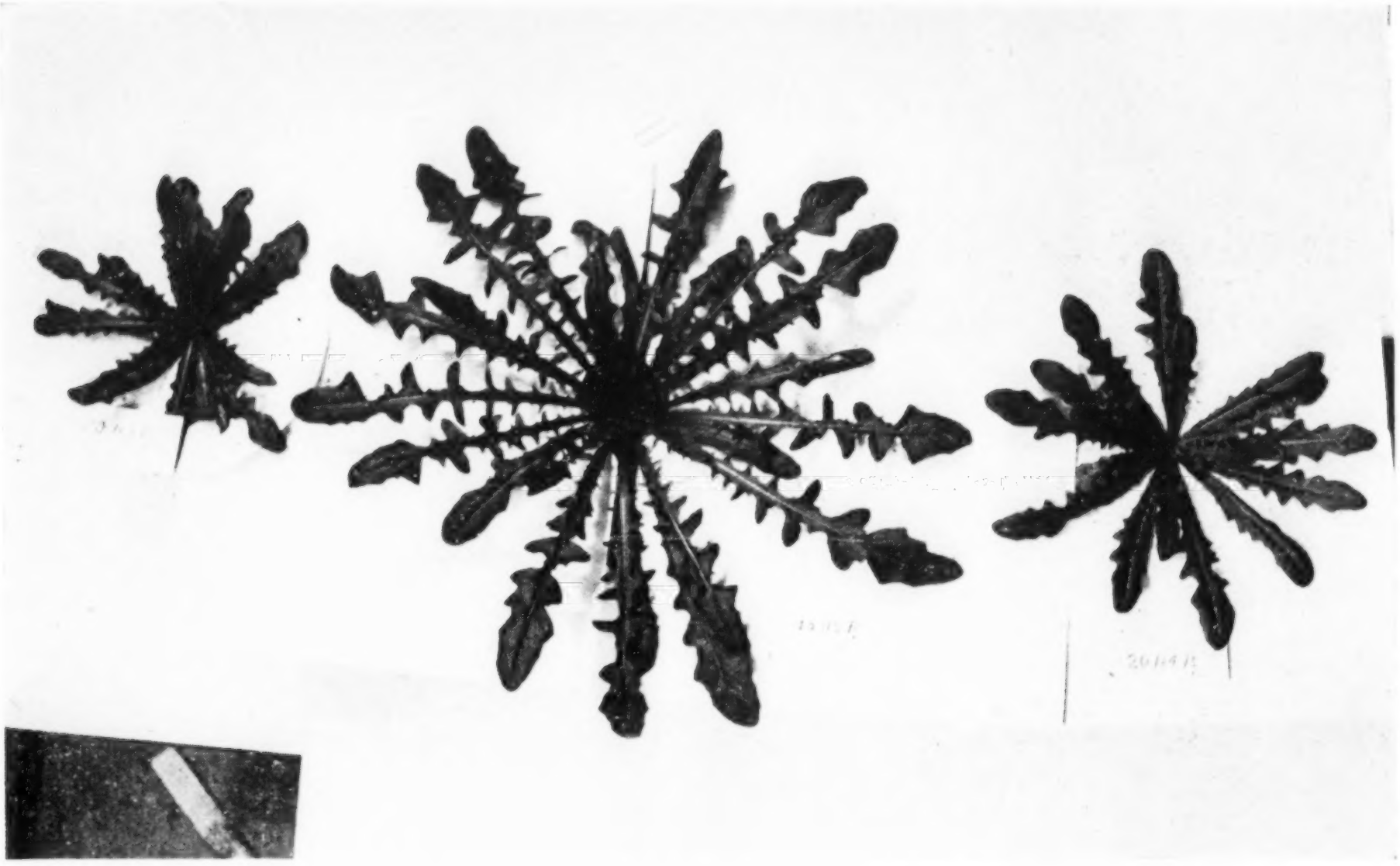
Crepis capillaris is a wild plant of the sunflower family. It is a native of the Mediterranean countries, and is growing wild in North and South America. Plants grown from seeds which were collected in two widely separated parts of California have shown interesting effects of cross-breeding and inbreeding. The hybrid plants (in the centre row) between inbred plants of the same age show pronounced hybrid vigor and development. (Fig. 31.)

were present in either of the parents. The linkage of such dominant genes to recessive genes or to dominant genes that influence size or vigor adversely reduces the possibility of securing such dominant races in a homozygous condition. For this reason the vigor noticed in the F_1 generation is less marked in the F_2 and subsequent generations where segregation and recombination of the genes of the F_1 are made evident. Most of our knowledge regarding inbreeding and crossing of inbred strains has been derived from experiments on maize, a plant which has been subject to artificial selection for centuries since its domestication. The question has arisen whether a cross-fertilized species which had never been domesticated and thus subjected only to natural selection would exhibit inbreeding and cross-breeding results similar to that described above. The answer to such a question will require controlled experimentation upon a number of species, but a beginning has been made with *Crepis capillaris*, a wild cross-fertilized plant belonging to the sunflower family.

INBREEDING REDUCES VIGOR AND SIZE IN CREPIS

Crepis capillaris is a native of the old world, found particularly in the countries about the Mediterranean and spreading out over Europe, Asia, Africa and adjacent islands. It has been introduced and is growing wild in both North and South America. The flowers are perfect, and both cross and self-fertilization takes place. No records have been found where this plant has been subjected to extensive selection or domestication inasmuch as it has no properties of economic value.

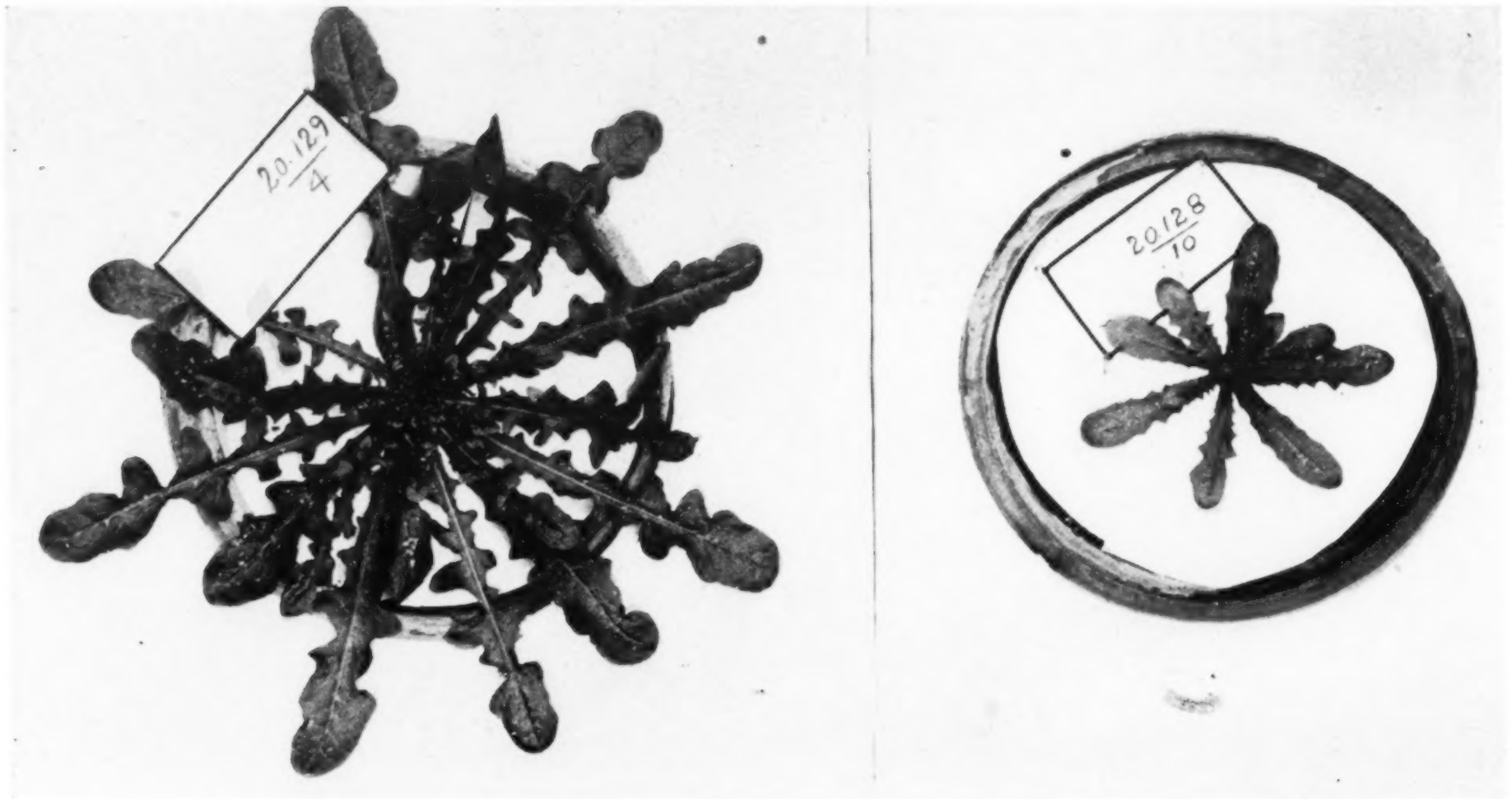
Seed collected from wild plants growing in two locations about 300 miles apart in California were used in the experiments of inbreeding. At the beginning of the experiment the plants were very similar in most characters and in size. The practice of inbreeding was started to purify the material which obviously was heterozygous. In the second generation of inbreeding there was some evidence of reduction in vigor and size, but the results of the 3rd and 4th generations left no question as to what was taking



ONE HYBRID PLANT (IN THE CENTRE) AND TWO INBRED PLANTS FROM THE GROUP SHOWN ON THE OPPOSITE PAGE (FIG. 32)

SAME PLANTS AS THOSE ABOVE PHOTOGRAPHED SIX WEEKS LATER

This shows the rapid development of the hybrid (at the left) which has produced a flower while the inbred plants have not started to produce a flowering stalk. (Fig. 33.)



A FIRST GENERATION HYBRID COMPARED TO AN INBRED PLANT

The greater vigor of the hybrid at the left is evident in this comparison with the inbred plant which shows slower development and total size. Both hybrid and inbred plants were grown in both four and six inch pots but the increased root space and quantity of soil did not alter the relation of vigor in the plants. (Fig. 34.)

place. These plants were smaller and much slower in growth than non-inbred plants. Inbreeding in this wild plant which is in nature largely cross fertilized does cause marked reduction of vigor and rate of development. Thus both they and maize behave in a similar way when subjected to inbreeding.

When inbred non-related strains of corn are crossed the progeny show a return to the size and vigor of the parents before inbreeding was practiced. In order to compare the wild plant Crepis with the domesticated plant maize in this respect, the inbred strains of Crepis were crossed together and to non-inbred strains. The results (Figs. 31 to 34) of these crosses again confirmed the similarity of the behavior of inbred maize and inbred Crepis.

The plants under domestication are not subjected to the same severe natural selection agencies common to wild plants. It is therefore possible for characters to exist in cultivated plants which would not be able to persist in a wild state. One would expect that the germplasm of wild species would be to a considerable extent purified of the genes which cause the production of harmful and abnormal characters by the elimination of most of the weak forms through natural selection. These experiments with Crepis however show that the germinal material is far from being in a state of purity or a state of homozygosity. If it had been nearly homozygous little reduction would have resulted when continued inbreeding was practiced and we would have had a condition similar to that in barley, wheat and peas where inbreeding (the normal method of reproduction) does not cause a reduction in general vigor or in rate of growth.

FOUR GENERATIONS

In Figure 31, cultures 113 and 114 are plants that have been subjected to inbreeding for four generations. The plants marked 115 are F_1 hybrids produced by crossing the inbred strain to a non-inbred and non-related strain. All plants were grown in four inch clay pots and were arranged, during their growth period, with hybrid plants between inbred plants as in Figure 31.

Inbred and hybrid plants were also grown in six inch pots but as shown in Figure 34, the increased root space

and quantity of soil did not alter the relation of vigor between inbred and hybrid plants. The marked increased rate of growth and development of the hybrid plants is shown in Figures 32 and 33 which represent the same plants, a time interval of six weeks between photographs. In Figure 34 the hybrid plant is in flower and has been bagged in order to secure the hybrid seed. The inbred plants are so much slower that they have not started to produce a flowering stalk. The similarity of behavior of maize and Crepis regarding inbreeding and crossing of inbred strains indicate a certain similarity of germinal conditions between a species long domesticated and thus subject to artificial selection and a wild species which has never been subjected to such selection.

This brings up a question whether domestication of a cross-pollinated species accompanied as it is with artificial selection changes in any appreciable extent the relations of the factors conditioning vigor, rate of growth and development from the relations they had in the wild species from which the domesticated species originated.

INHERITANCE OF MENTAL TRAITS

Evidence that Heredity Determines the Make-up of the Mind as Well as the Body Is Reviewed by Starch

PAUL POPENOE

SO LONG as psychologists depended on introspection for their science, it was possible for some of them to believe that mental traits are not inherited. The doctrine of the child's mind as a blank sheet of paper, on which the environment and the teacher wrote their autographs, had followers.

But with the development of precise and objective methods in psychology, students were rapidly forced to realize that the mind was not in a realm by itself; for they came up against facts that could be satisfactorily interpreted only by the supposition that differences in mental ability are inherited in the same manner as, more obviously, are differences in physical ability.

Thus it is, according to Daniel Starch, that among psychologists "the view held by most scientific students of the problem today gives weight to both elements, with perhaps the major emphasis on heredity."

Dr. Starch's recent and well-documented book[1] on educational psychology discusses three of the numerous lines of evidence that have caused this recognition of the importance of heredity. These lines are: (1) The similarity of abilities among related persons; (2) the influence of uniform environment on different original abilities; and (3) the influence of different environments upon similar original abilities.

THE HISTORICAL APPROACH

1. Correlation of abilities may be studied most conveniently either at one extreme of the population or the other; either among those who are talented or among the feeble-minded and other defectives. The problem was first attacked, historically speaking, among the eminent, by Francis Galton, and was followed up much later by Frederick Adams Woods.

Galton made a study [published in 1869] of 977 eminent men, each of whom was the most eminent among 4,000 persons. He proceeded to determine how many relatives of equal eminence and of varying degrees of relationship each person possessed. In this manner he found that these 977 men had the following relatives of a like degree of eminence: Fathers 89, Brothers 114, Sons 129, Grandfathers 52, Grandsons 53, Uncles 53, Nephews 61; Total 535.

[1] Educational Psychology, by Daniel Starch, Ph.D., University of Wisconsin. New York: The Macmillan Co., 1920. Pp. 473, with 96 text figures.

"Galton further pointed out that 977 ordinary men, selected by chance from the population at large, would have only four such eminent relatives. He concluded as follows:

"(*a*) That men who are gifted with high abilities easily rise through all the obstacles caused by inferiority of social rank.

"(*b*) Countries where there are fewer hindrances than in England, to a poor man rising in life, produce a much larger proportion of persons of culture, but not of what I call eminent men. [England and America are taken as illustrations.]

"(*c*) Men who are largely aided by social advantages are unable to achieve eminence, unless they are endowed with high natural gifts."

In 1906 F. A. Woods published his study of "Heredity in Royalty," in which he analysed the principal reigning houses of Europe, showing that the really great persons in them were closely interrelated and that the right of succession to the throne, which gave great opportunity to a man to achieve distinction, did not suffice to produce real greatness where it did not germinally exist as the result of inheritance. Dr. Woods concluded that heredity "explains at least 90% of the intellectual side of character in every case," an induction that Dr. Starch thinks is too high.

At the other end of the scale, among the defectives, delinquents, and degenerates, there is no lack of studies, largely American, to show how feeblemindedness, for example, runs in families. The Jukes, the Zeros, the Kallikaks, and others are cited by Dr. Starch, somewhat uncritically.

BAD ENVIRONMENTS

"To one who wishes to argue in favor of environment as the chief determining element in ability and character," he goes on, "such data as have been presented from family histories and relationships are not entirely convincing. It might be argued that a given family has so many individuals of high or low intelligence and achievement because its members were born in circumstances which did or did not afford opportunities for development and training and for achieving higher success. It might be said that the descendants of the [Jonathan] Edwards family were born and reared among favorable circumstances of educational and financial advantages and consequently were fitted for greater tasks and lived in an environment in which larger opportunities offered themselves, whereas the members of such a lineage as the Jukes family would have just the opposite environment of birth, education, and opportunity in life.

"In answer to all this, we must remember, however, that ability very largely determines the sort of environment in which a person is satisfied to live, that a really capable person is quite likely to push forward and to find a way out of the environment in which he may happen to have been born, or to improve it if he cannot leave it, and, finally, we must remember that the persons of low ability were born in circumstances of a correspondingly low nature because of the hereditary stock of the families from which they came. Their parents were content to live under the circumstances under which they did live, because their abilities and desires sought for nothing better."

BROTHERS AND SISTERS

Dr. Starch then proceeds to the correlations of measurements between brothers and sisters in mental traits which, just as for physical, average around +0.50. He describes a study of his own on students of the University of Wisconsin in which it appeared that "the resemblance of siblings is apparently no greater in those mental traits which are directly affected by school work than in those which are not so affected. The average correlation in the former group of tests is 0.42 and in the latter 0.38. This seems to indicate that the mental similarities of children of the same parents are due primarily to heredity rather than to similarity of environment, since the resemblance is no greater in those traits, which are more directly affected by environment."

Similar work by E. L. Earle is explained. The conclusion of this investigator was that "abilities in special subjects are inherited, apparently to no greater extent in one subject than in another. What is probably inherited is either general scholarship or else more specialized traits than ability in arithmetic, or ability in language. Each study involves many mental faculties and nearly all studies involve the same faculties with varying emphasis.

"There is no evidence, at least from these figures, for the notion that special abilities in certain studies run in families. Mental traits running in families are very likely more specialized than abilities in school studies which involve large groups of mental functions. The children of any given family are on the average equally good or equally poor in all studies. Ability in school work is apparently inherited to the same extent as physical features, since the coefficients of correlation for children of the same parents are approximately the same for both physical and mental traits."

The study of 185 pairs of sibs in the University of Wisconsin, made by Miss Emily S. Dexter, showed a resemblance of about 0.60 in scholarship records in various subjects. Her judgment is "that inheritance, to a much greater extent than training, is responsible for the degree of resemblance found." One of the bases of this judgment is that sibs of opposite sex were found to be more closely correlated than those of the same sex.

Several other studies of this sort, and the *familiar* studies of twins by Francis Galton and by E. L. Thorndike are also cited.

EFFECTS OF PRACTICE

2. The influence of uniform environment upon different original abilities has been measured by various psychologists. "All experimental results point in the direction that practice does not equalize abilities," Dr. Starch declares. "In fact, equal practice tends to increase differences in achievement and skill rather than to decrease them. The more gifted individuals profit more, both relatively and absolutely, than the less gifted. This experimental fact is one of the most profound bits of evidence regarding the whole problem of heredity and environment. The talented men not only start with greater initial capacities but seem also to be capable of more intense application and more zealous desire to improve. 'To him that hath shall be given' is psychologically true in the sphere of intellectual training as well as in the sphere of morality and religion."

"If we may generalize for life as a whole, equal opportunities for all do not produce equal abilities in all. Men may be born free politically; but they are not born equal mentally; they may be born equal in opportunities in a democratic society, but they certainly are not equal in their ultimate achievements in life."

3. Influence of different environments upon various original abilities has likewise been tested by more or less exact methods on many different occasions. Dr. Starch considers these studies somewhat uncertain in interpretation; they can be made to prove anything. He has, however, ignored one of the strongest pieces of evidence under this head, which is a matter of every-day observation—namely, the persistence of inherited qualities in brothers and sisters who are brought up in widely separated surroundings. The case is the more striking if twins are studied.

Indeed, it is easily possible by more methodical classification of the data available to make out a much stronger case for heredity than Dr. Starch has done. His case, however, is strong enough to make him say:

THE CONCLUSION

"The general impression from all experimental, statistical, and historical material thus far accumulated on the problems of mental heredity would seem to be somewhat as follows: Barring paupers, invalids, and those suffering from want of food and shelter due to conditions beyond their personal control, and referring to all others liv-

ing in the same community at the same time, the ultimate achievement of any given individual is due to his original ability, probably to the extent of 60% to 90%, and to actual difference in opportunity or external circumstances only to the extent of 10% to 40%."

"The facts of heredity bear down so heavily," he continues, "that the impression gained of the large part played by it leads one almost to a fatalistic philosophy. One is almost inclined to believe that persons become what they do largely on account of their hereditary capacities, and that they are not in the least responsible for their own outcome; that if a person is born with great capacities he will achieve high distinction, and if he is born with mediocre or slender capacities he will not achieve anything beyond his limits, no matter what he may do.

"While it is certainly true that no one may achieve a position higher than his original capacities will permit, it does not follow that a mechanical, fatalistic view needs to be taken. Nature predominates enormously over nurture only in the relative and not in the absolute sense.

THE POSSIBILITIES OF NEWTON

"This distinction must always be borne in mind in studies of heredity. In fact, in the absolute sense, nurture predominates enormously over nature. A Newton born among Australian bushmen would no doubt have become a remarkable bushman, but never a world-renowned scientist. The necessary stimuli of environment must be at hand to train and develop original capacities.

"The difference between relative and absolute achievement may be illustrated in any of the experimental results concerning the effects of equal practice, cited in a preceding section. The fact that all individuals improve by practice shows absolute gain in performance or skill. The fact that the gifted ones maintain their lead, or even gain in their lead, is relative achievement. Before practice, no child can write; after practice, all normal children can write with more or less excellence. This is absolute gain. Before practice, some children have greater original capacities for learning to write; after practice, these same children maintain the same superiority. This is relative gain.

"A Newton and an ordinary bushman born and reared among bushmen would probably be superior and ordinary bushman respectively. A Newton and an ordinary bushman born and reared in New York City at the beginning of the twentieth century would probably become, respectively, the one a great scientific, professional, or business man, and the other an ordinary person, able to get on, earn a living, and enjoy life within the ordinary limits.

THE PRESSURE OF CIVILIZATION

"The original abilities of ancient civilized peoples were probably very little different from the original abilities of modern civilized peoples. The differences are probably due to the transformation of the environment, which is constantly being brought about through the efforts of man. A Newton born in a modern civilized community would have greater and different stimuli than one born in an ancient or uncivilized community. His ultimate eminence would be determined by his environment.

"The pessimistic air may be further dispelled by noting the fact that hardly one person in a thousand makes all the absolute gain possible for him even in a single capacity. It has been proven over and over again in numerous abilities which have been used daily in one's occupation that by a little special practice each day their efficiency can be enormously improved. Consequently, while the possibilities of each individual are limited by his original inherited equipment, each one may develop his capacities far beyond the normal degree of attainment.

"While experimental evidence indicates emphatically that under equal opportunities the more gifted surpass the less gifted, yet rarely does anyone do his best or attain his limit even in a single capacity. Life is a matter of competition: let everyone compete to the fullest extent of his inherited ability."